MAY 30, 1957

MACHINE DESIGN

A PENTON PUBLICATION — BIWEEKLY

Mechanics of Vehicles

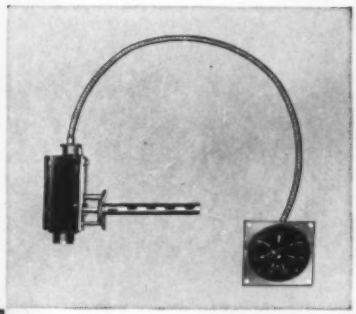
Contents, Page 3

S. S. White

Flexible Shafts Withstand Temperature Extremes!

A leading aircraft manufacturer has used S.S. WHITE flexible shafts for many years to transmit control between this graduated dial and aircraft thermostat. He finds that under any kind of temperature conditions, there is no measurable variation in torque to turn the shaft, or in torsional deflection required to initiate cam movement over the temperature range!

This ability to withstand temperature extremes is only one of the many remote control and power drive advantages industry has discovered in S.S. WHITE flexible shafts. Perhaps they can help you to simplify control or product design . . . cut your production costs . . . speed assembly. These quality shafts range from small to large sizes, and up to 12 feet in length. The assistance of our engineering staff in helping you work out a flexible shaft application for your product is yours for the asking. Just write to



S. S. White

FIRST NAME IN FLEXIBLE SHAFTS

USEFUL DATA on how to select and apply flexible shafts. Write for Bulletin 5601.

S. S. White Industrial Division, Dept. 4, 10 East 40th St., New York 16, N. Y. Western Office: 1839 West Pico Blvd., Los Angeles 6, Calif.

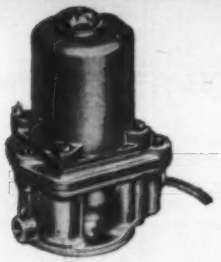
Circle 401 on page 19

NEW Ross Starline

air control valve series

NEW long life

WHITE STAR
SPOOL SOLENOID



GOLD STAR
OIL-IMMERSED SOLENOID

BLUE STAR MV

BLUE STAR TD

BLUE STAR WV

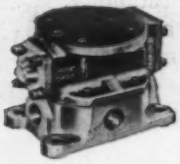
NEW match any head to any valve body!

STRAIGHTWAY
NORMALLY
OPEN

STRAIGHTWAY
NORMALLY
CLOSED

3 WAY
NORMALLY
OPEN

3 WAY
NORMALLY
CLOSED



3 WAY
NORMALLY
OPEN

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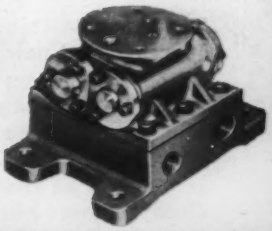
CLOSED



4 WAY

Tests indicate a trouble-free life of over 25 million cycles for valves with the spool solenoid pilot section, and *more than 40 million for all other Starline* valves shown.

Heads and bodies are completely and instantly interchangeable. Sizes from ¼" to 1¼". Even *more* Starline models coming later. Write for Starline data file.

A Galaxy of New Air-Control Stars Are Coming Your Way From

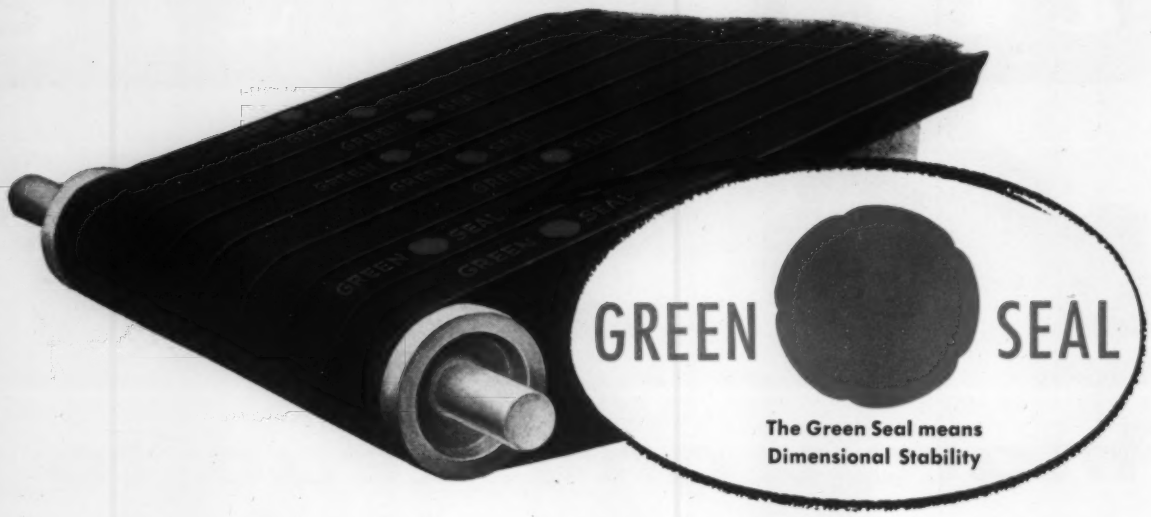
Ross OPERATING VALVE COMPANY

1009 EAST GOLDEN GATE AVENUE • DETROIT 3, MICHIGAN

Circle 404 on page 19

Another Goodyear First:

V-Belts *with the* Green Seal



stay matched from factory to drive

The Green Seal signifies true dimensional stability. It means that now when you reach for a matched set of V-belts, you can be sure they're matched – no matter how long they've lain on the shelf. And that means longer life and a minimum of down time.

It used to be that only steel-cable V-belts by Goodyear were length stabilized. But now, through the miracle of Triple-Tempering, they've been joined by all the other Goodyear Industrial V-belts.

Triple-Tempering is the exclusive process wherein synthetic cord is carefully brought to the peak of strength and stability by controlled tempering with Tension, Temperature and Time. And this gives you not only *length* stability in storage, but greater shock- and stretch-resistance on the drive.

In addition to 3-T load-carrying members, the Green Seal also brings you "balanced construction." This means each component of the belt is specifically designed to its job to give you cleaner, smoother, longer running which adds up to maximum, trouble-free horsepower hours at minimum cost.

The next time you need V-belts, be sure they're wearing the Green Seal–the mark of a V-belt made with the technical know-how of the world's largest rubber company. They're readily available at your Goodyear Distributor. Or write for details to Goodyear, Industrial Products Division, Lincoln 2, Nebraska, or Akron 16, Ohio.

DIMENSIONALLY STABLE V-BELTS by

GOODYEAR

THE GREATEST NAME IN RUBBER

Green Seal—T. M. The Goodyear Tire & Rubber Company, Akron, Ohio

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MAY 30, 1957
Volume 29—No. 11
THE PROFESSIONAL JOURNAL FOR ENGINEERS AND DESIGNERS
MACHINE DESIGN

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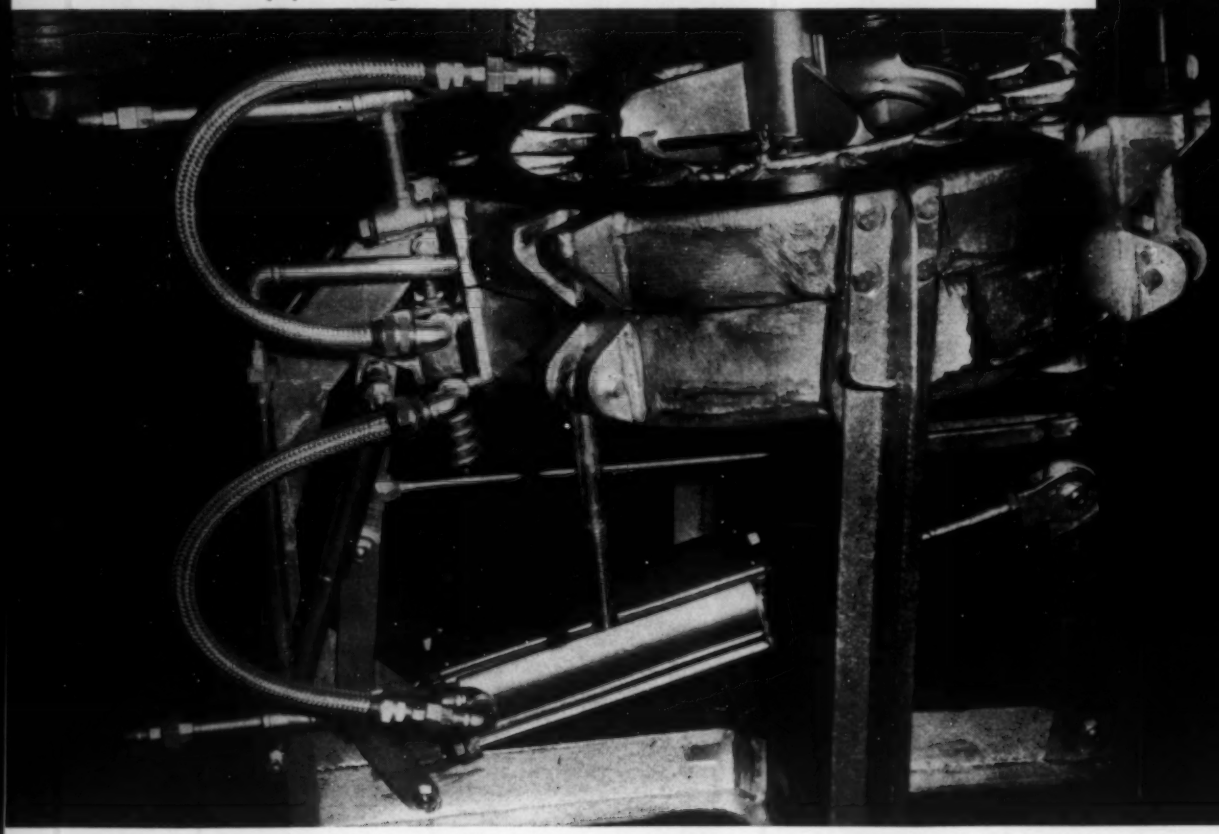
Where your problem is pipe that must flex

reduce pipe fatigue with American flexible metal hose



300°F, 50 lb. pressure is met by American Flexible Bronze Hose connecting moving steam chambers on Super Mold tire capping equipment.

"American flexible metal hose is tops for trouble-free service!" says C. R. Lohr of the Super Mold Corporation. Since 1940, American flexible metal hose has been conveying steam between moving parts on Super Mold tire capping equipment.

Whether frequency of flexure is a few times a week . . . or a thousand times an hour . . . you'll find American flexible metal hose is tight, safe, long lasting, easy to install. In field and laboratory tests American flexible metal hose has flexed millions of times without sign of failure.

Problems Solved by American Flexible Metal Hose

American flexible metal hose absorbs vibration and prevents its transmission to surrounding structures . . . absorbs expansion and contraction in lines due to temperature changes . . . facilitates installation especially in cramped spaces . . . solves the problem of misalignment.

Available in wide range of diameters in tough bronze, steel, super nickel, brass, stainless steel and other metals. American hose, complete with fittings, is made to your specifications and ready for immediate installation.

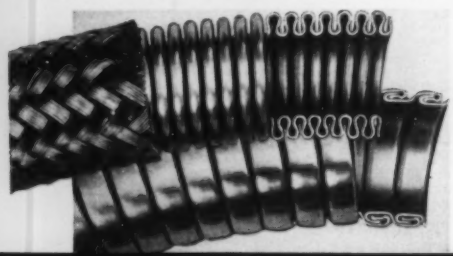
Consult your nearby American Metal Hose representative for engineering help when planning your next job. No obligation. See American Brass Company or Anaconda in your phone book — or write: American Metal Hose Division, American Brass Company, Waterbury 20, Conn. In Canada: The Canadian Fairbanks-Morse Co., Limited.

WHEREVER CONNECTORS MUST MOVE

66181 Rev.

AMERICAN FLEXIBLE METAL HOSE AND TUBING

AN **ANACONDA®** PRODUCT



BASIC TYPES

Seamless corrugated and Strip-wound. Both types available in a wide range of sizes and styles in any workable metal. Furnished with or without end fittings attached.

THE AMERICAN BRASS COMPANY
American Metal Hose Division, Waterbury 20, Conn.

Please send me a free copy of your new flexible metal hose and tubing catalog, G-560.

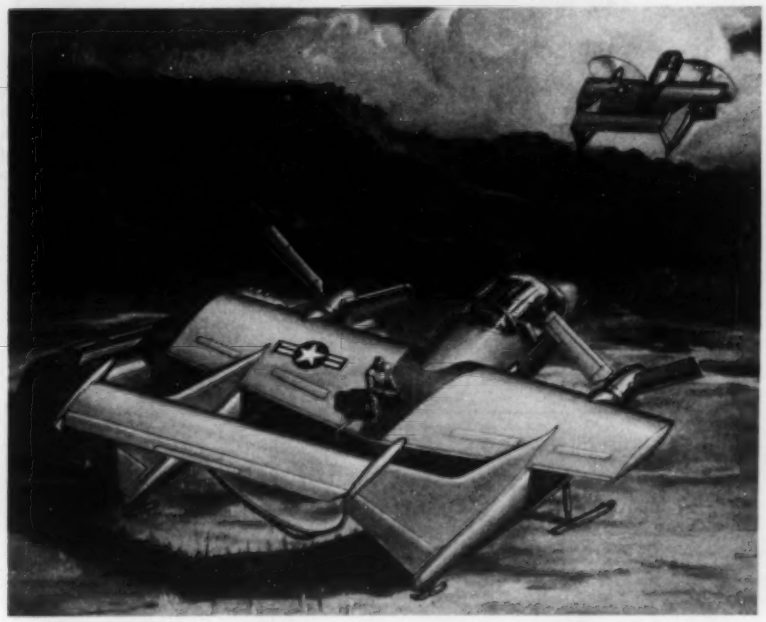
NAME & TITLE.....

ADDRESS.....

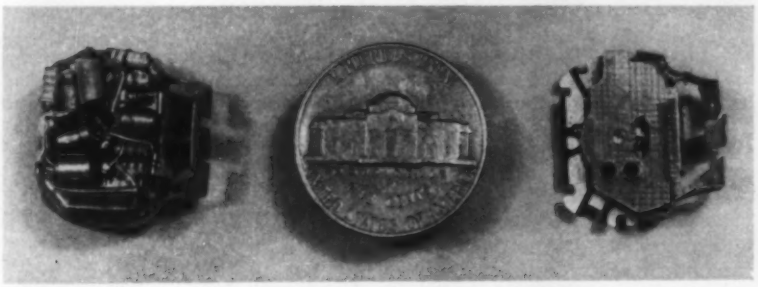
COMPANY.....

CITY, ZONE, STATE.....

Engineering News Roundup



FLAP-FITTED PROPELLERS will distinguish this new plane to be built for the Navy by Kaman Aircraft Corp. Intended as an STOL aircraft (short take off and landing), the gas-turbine-driven plane will have two propulsive rotors with controllable flaps buried in their trailing edges. These and similar flaps in the wings will provide lift and control necessary for air speeds under 50 mph. Above 50 mph, the flap system will automatically phase out and conventional plane controls will take over.



AMPLIFYING SOUNDS MORE THAN 400 TIMES, this new hearing aid, claimed the world's smallest, is worn entirely in the ear. It has no cords, receiver buttons, bridges or outside wires. It corrects hearing losses up to 50 decibels. Designated model 222 by Sonotone Corp., the new aid is ¾-in. long, ¾-in. high, and 13/16-in. wide. It weighs ½-oz. Cover removal reveals compactness, above. Components include three transistors and a battery with a life of 50 hr. A built-in receiver contains 1100 turns of wire only 0.0015-in. diameter. Cover for the model 222 is stainless steel finished in an assortment of colors of anodized aluminum.

←Circle 406 on page 19

Pentagon Will Now Be Heard 'Round The World

Transmitter With 150-lb Tube Overcomes Severe Interference

WASHINGTON, D. C.—Any spot on the earth will be reached with a powerful new short wave transmitter to be installed in the Pentagon. The new radio will put through vital messages despite severe interference, according to the Dept. of the Army.

Called the World Spanner, the transmitter was designed by the Army Signal Engineering Laboratories and Continental Electronics Inc. It is almost 50 times more effective than the loudest commercial broadcasting station.

The set owes its tremendous power to single sideband design. This is an electronic technique which concentrates the power of a transmitter's signal. Conventional transmitters broadcast three separate signals—a carrier wave and two duplicate sidebands. Single sideband circuits filter out the carrier wave and one sideband, thus funnelling all of the power into the remaining sideband. This provides eight times the strength of conventional transmitters with the same power supply.

With ordinary design, the World Spanner would have a power of 300,000 w—more than enough to light 100 homes. With the new single sideband refinements and a new beam antenna now under development, effective power will reach 24-million w. Main tube of the World Spanner weighs 150 lb and operates at 18,000 v.

Changing channels on a high-power station is usually a major job, but the World Spanner will be almost as easy to tune as a pushbutton radio. An operator can go on the air at any one of ten previously set frequencies by turning a single switch. The trans-

mitter easily sends 64 teletypewriter messages or four separate voices at the same time.

Compact design makes the World Spanner smaller than transmitters with far less power. With all accessories, it can be housed in a 50-ft square room. Maintenance is simplified despite this compactness.

World Spanner can transmit at any frequency in the short wave spectrum from 4 to 30 megacycles, and a second version will cover the range from 20 to 65 megacycles.

Gun That Shoots at Itself Is Fast-Acting Wind Gage

Boomerang Operation Yields Raw Weather Data

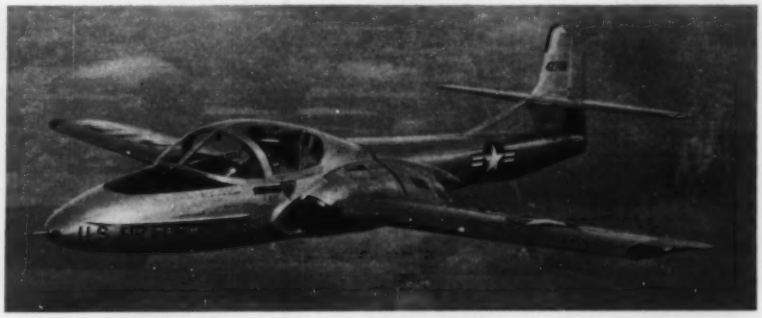
WASHINGTON, D.C.—A weather gun that shoots at itself with a round-trip bullet is the latest experimental device announced by the Army for measuring low-altitude wind velocity. The gun will be used at launching sites where data it supplies will help to aim and launch missiles. The first few hundred feet of a missile's flight are critical. Even relatively low winds have a significant effect.

Rifle ball's time of flight determines velocity of the wind over the target.

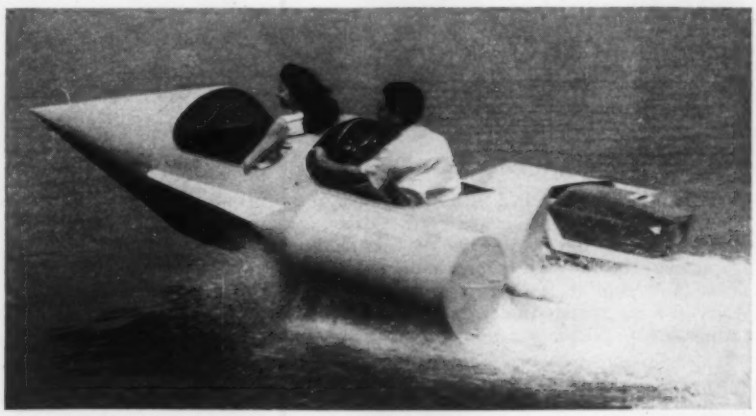
The weather gun was designed at the Army Signal Engineering Laboratories and is officially called Shooting Sphere Anemometer. It is a smooth bore gun that fires a small steel ball upward into the wind at an angle calculated to make the ball fall back into or near the gun's own muzzle.

Before firing, the gun is angled into the wind. The stronger the wind, the greater the angle. Successive approximations may make several firings necessary. A successful firing occurs when a returning ball strikes the shield around the gun muzzle. Then the operator compares the gun's angle of tilt with a calibration chart to obtain the wind velocity.

A stop watch and the same chart



TWIN-JET TRAINER, designated T-37A and built by Cessna Aircraft Co., will soon be delivered in quantity to Flying Training Air Force. Student pilots fresh from civilian life will take primary flight training in the new jet. Instructor's position is beside the student to help build student confidence and facilitate communication. The T-37A is 29 ft long, has 33-ft wingspan, weighs 6400 lb with full fuel load. Powered by two J69 Continental engines, each rated 920-lb thrust, the plane flies faster than 300 knots below 10,000 ft altitude. Despite this speed, it can easily land on and take off from runways as short as 2000 ft. Cessna-developed thrust-reduction device on the T-37A enables slow landing approaches while high engine rpm is maintained in case the maneuver must be repeated.



JET-LIKE CRAFT, 14 ft long, is made by Cheston L. Eshelman Co., entirely of 16-gage cold rolled steel in regular geometric shapes. The Rocket Boat weighs 425 lb; seats four. Recommended power is a 25-hp outboard. Maker claims submerged objects won't puncture the hull and that rain pouring inside won't sink it. Outrigger pontoons make the Rocket Boat stable.

Front Cover

With the 500-mile Memorial Day races taking place in Indianapolis this week, the subject of artist George Farnsworth's front cover is particularly appropriate. Showing some of the forces acting on a rolling wheel, the cover highlights Jerry Taborek's article on Page 60.

. . . Fluid Power news

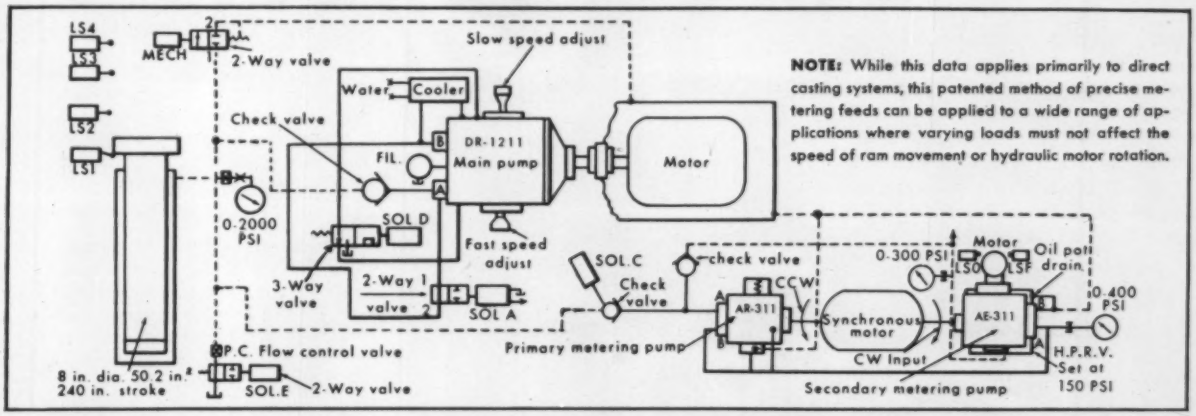
REPORT NO. 11,800 POSITIVE FEED RATES

From Oilgear Application-Engineering Files

HOW OILGEAR SYSTEM ACCURATELY HOLDS DIRECT CASTING FEED RATES

CUSTOMERS: *Large aluminum and magnesium alloy producers*

DATA: Feed equipment for direct casting of light metal alloy extrusion rounds and sheet ingots. The entire cast—or drop—takes about 60 minutes at a rate of 3 ipm to ingot lengths of 15 ft. or more, depending on the size of furnace heat. Avoidance of internal cracking, homogeneity, grain structure fineness and orientation depend on rate of cooling, pouring speed, and subtle control of all variables. Must be "fail-safe" and complete cycle in event of power failure. Casting platform to have both up and down rapid traverse; and controllable, stoppable, steady, slow, down feed rate regardless of platform load.



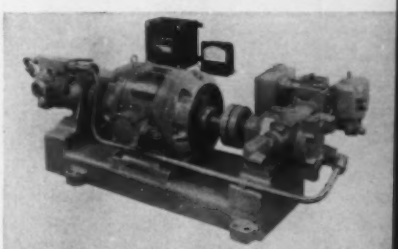
NOTE: While this data applies primarily to direct casting systems, this patented method of precise metering feeds can be applied to a wide range of applications where varying loads must not affect the speed of ram movement or hydraulic motor rotation.

SOLUTION: A new, patented, Oilgear Fluid Power control system that provides accurate volumetric metering of pressurized oil over a 200:1 pressure range, and a 100:1 feed range. A typical installation consists of an Oilgear "DR-1211" variable displacement pump with 10 hp electric motor on a custom-built base; Oilgear "AR-311", "AE-311" precision variable displacement metering pumps driven by a 3 hp, double-end, synchronous electric motor; an Oilgear 8" bore x 240" stroke, single acting cylinder; and Oilgear valves and controls. The "AR" and "AE" metering pumps are connected in series hydraulically between the cylinder and oil reservoir. During pouring, ram down-feed is dependent on control setting of secondary "AE-311" metering pump—remotely controlled by pushbutton to provide instant, accurate, feed rate adjustment from 0 to 25 ipm. Casting feed rate is indicated in ipm on a direct reading indicator . . . can be preset accurately, and changed at will. Oil under varying pressures flows from cylinder through sealed, "pressurized" type "AR-311" metering pump—and then at a relative constant low pressure through "AE-311" metering pump to reservoir to provide extremely accurate casting feed rates regardless of varying platform load. An automatic, hydraulic control varies "AR-311" pump displacement to compensate for load variation, and feed selected.

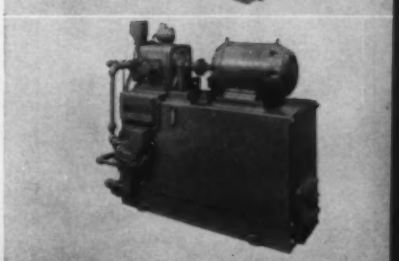
TEST REPORT: "Where load on the platform varied the oil pressure from 50 to 1,500 psi, and rate of flow was preset anywhere between 50 and max. cipm, *there was no measurable change in the preset rate of casting feed during any portion of stroke.*"

For practical solutions to your linear or rotary drive and control problems, call the factory-trained Oilgear Application-Engineer in your vicinity. Or write, stating your specific requirements, directly to . . .

HERE'S HOW—oil flow is controlled by this new, patented, Oilgear system. When solenoid "A" is energized, oil delivered by "DR-1211" flows out port A to cylinder ram; when de-energized, main pump flow is bypassed. When solenoid "D" is energized, pump delivers maximum volume set by fast speed adjustment; when de-energized, pump delivers minimum volume set by slow speed adjustment. If upper limit switch is over-run due to switch or current failure, mechanically operated 2-way valve is opened by ram overtravel bypassing oil providing fail-safe "up" operation. In normal operation, solenoid "E" is energized, blocking oil flow through flow control valve. If power fails solenoid "E" is de-energized allowing oil to flow from cylinder through flow control valve to continue pouring stroke. Ram can be stopped in this situation by closing flow control valve. When pouring starts, solenoid "C" is energized opening check valve, metering oil through series connected primary and secondary pumps back to the reservoir. All solenoids except "E" are de-energized when ram is in idle position, blocking flow from cylinder to hold ram and platform stationary. Oil from small integral gear pump when blocked by higher pressure on mechanical check valve bypasses through cooler to supercharge main and metering pumps. It also lubricates metering pumps when ram is idle.



Metering pump unit with "AR-311" (left), "AE-311" and gear-head pilot motor to right, direct-connected to a double-end, 3 hp synchronous electric motor.



Oilgear "DR-1211" variable displacement pump provides adjustable, preset, slow and fast speeds for raising (and lowering) the platform. Max. volume is 8,140 cipm for max. "up" speed of 162 ipm at any force up to 67,500 lb. with an 8 inch ram.

THE OILGEAR COMPANY

Application-Engineered Fluid Power Systems

1568 WEST PIERCE STREET • MILWAUKEE 4, WISCONSIN

Please direct inquiries to advertiser, mentioning MACHINE DESIGN

give the altitude at which the wind is being measured. A 5-second lapse between firing and return indicates that the ball reached a height of 100 ft. Approximate height can be controlled by selection from assorted precharged cartridges. In tactical application, the device would be used for readings up to 500 ft above the ground.

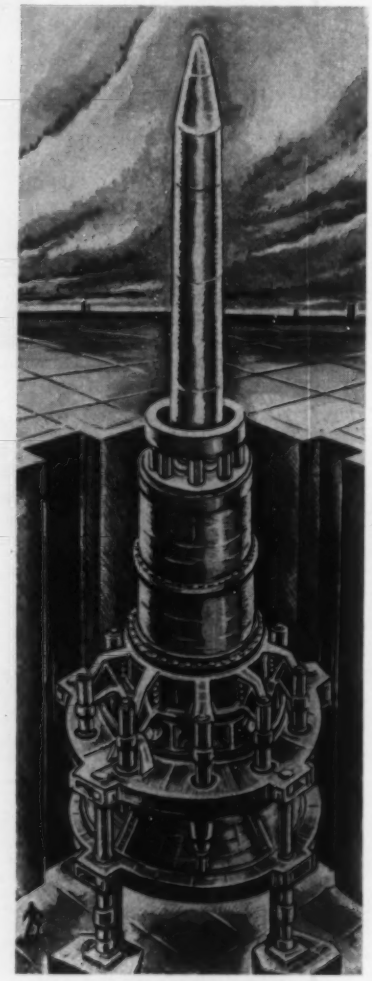
The Signal Corps sees a number of advantages of the gun over small weather balloons now used for low-level wind measurement: The weather gun measures wind speed at the testing point. Its small steel spheres are inexpensive and cannot be spotted and shot down by the enemy. It can be used under poor visibility conditions and can measure velocities up to gale force. The gun also gives information faster than balloons.

Television-Type Microscope To Extend Small Studies

BOSTON, MASS.—One million particles per second can be analyzed and measured in a new television-type microscope developed by the Allen B. DuMont Laboratories Inc. This compares with a human limit of about 40 bits of information per minute. The new product is called a "flying spot" microscope. Its optical and electronic system will make possible studies in microscopy never before undertaken because of inaccuracies due to human error and the spectral and other limitations of the human eye.

The flying spot microscope incorporates standard and conventional microscope optics, but the light source, instead of being the usual evenly illuminated plane, is a rapidly moving spot of light. This spot, produced by a beam of electrons inside a cathode-ray tube, is rapidly deflected by electrical techniques similar to those used in television.

The microscopic specimens, prepared in the usual manner on glass or quartz slides, are scanned in a regular pattern called a raster which consists of a series of sequential parallel lines. This raster is like the kind used in standard television systems.



SIMULATING ROCK AND ROLL at sea and launching the Navy's Fleet Ballistic Missile under these conditions will be the function of this new test installation. It will be built at the Air Force Missile Testing Center, Cocoa, Fla., by Loewy-Hydropress Div. of Baldwin-Lima-Hamilton Corp. Actual ship motions will be reproduced from magnetic tape recordings taken at sea. The system will determine dynamic thrust forces at take-off.

Variations in light transmissions of the scanned specimens are converted into electrical signals, and this information is displayed on an electronic viewer as an enlarged image of the microscope specimen. The viewer or monitor is similar to a television receiver.

Since the information about the

Topics

Private shower for a jet plane was provided a North American Aviation F-100C Super Sabre in a recent experiment, the object of which was to test the plane's windshield rain removal system. An Air Force KB-29 tanker, flying about 100 ft ahead of the F-100, released 3000 gal of made-to-order rain which varied in intensity from a drizzle to a downpour.

• • •

World's largest sling is the claim made by the Wire Rope Div. of American Chain & Cable Co. Inc. for a new giant-size model developed for moving heavy equipment. The sling is made from 3-in. diam wire rope. Its breaking strength is rated at 720,000 lb; working load is 144,000 lb.

• • •

Switch of pitch on 1957 Buick horns was made by using musical notes F and A instead of E-flat and G as in previous years. Reasons given for the change are that the higher notes penetrate road noise slightly better, and the new combination is felt to provide a more mellow and pleasing sound. The horn problem is a growing one in the automobile industry. Better insulation keeps out road noises; among them, of course, the warning sound of horns.

• • •

Giant-size solar furnace, 40 by 125 ft, is to be erected at the Quartermaster Research and Engineering Center at Natick, Mass., for laboratory testing of materials intended to protect military personnel against the thermal effects of nuclear and other weapons. The furnace will be capable of concentrating the sun's rays to produce temperatures comparable to those generated by an atomic explosion.

• • •

Industrial electric power consumption in 1963 will be 450 billion kilowatt hours, according to A. C. Monteith, Westinghouse vice president in charge of apparatus products. This estimate is 12½ per cent higher than a similar prediction made in 1954. Mr. Monteith observed that, since World War II, use of electric power has increased at a rate comparable to doubling every seven years.

Circle 407 on page 19→

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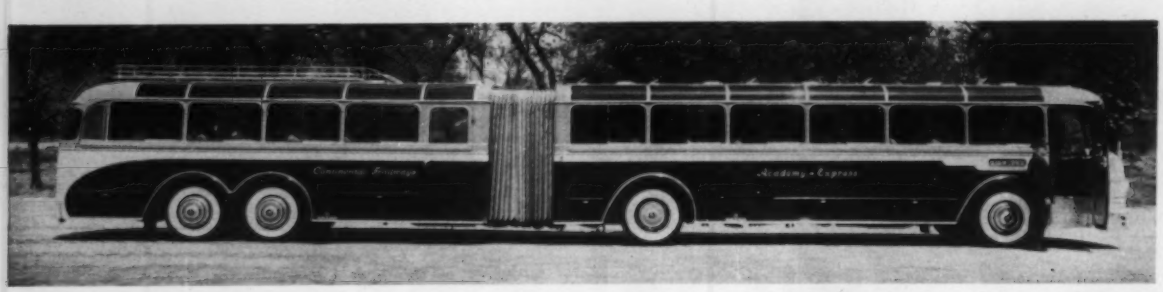


SIXTY FEET OF BUS stretch between front and rear bumpers on this new German-built model claimed first-of-type in the U. S. It is now in service on Continental Trailways' 113-mile run between Pueblo and Denver, Colo. Inside turning radius of the articulated coaches is 35 ft, where conventional bus needs 60 ft. The rear axle of the trailing unit tracks the turning point between the units. Turntable houses refreshment bar. A hostess attends 64 passengers. Built of steel and aluminum, entire bus weighs the same as 40-ft nonbending type. Each passenger has reading light, clock, inside thermometer and an altimeter.

specimen is in electrical form, it can be subjected to many types of electrical, photometric and histologic analyses by automatic computers and other rapid electronic means.

Brainstorming to Help Build New Medical Instruments

Doctors And Engineers Will Probe Problems in Novel Clinic

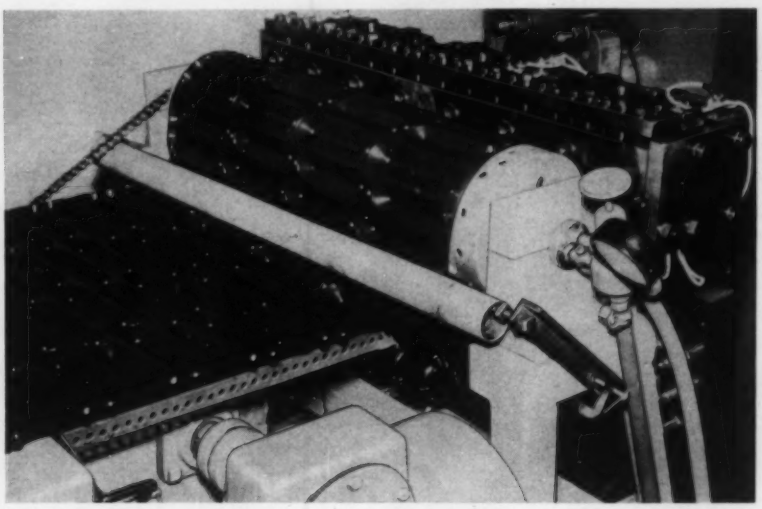
NEW YORK, N.Y.—Brainstorming will now be used to cross-fertilize the fields of medicine and instrumentation in experiments sponsored jointly by the Foundation for Instrumentation Education and Research and the New England Institute for Medical Research. Doctors and instrument designers will participate in a clinic to review knotty medical problems and to speculate on how instruments may help to solve them.

Cloistered for two days, June 10 and 11, 1957, at the Institute's laboratory in Ridgefield, Conn., the scientists, doctors and engineers will explore the potential of new instrument techniques for measuring and diagnosing physical and chemical variables in the human being.

The methods of the clinic will be unusual. First the instrument men will be exposed to an intense briefing, with demonstrations, on some of the baffling measuring problems in medical diagnosis and biology. A few specific diseases will also be covered. The technique of briefing will be most unique: The medical men will be primed to express themselves in physical and engineering terms. The clinic cosponsors hold that heretofore the vocabularies of the respective fields have hindered effective communication between them.

The instrument professionals will then hold the floor. Their suggestions for new ways to attack the measuring problems will be picked at and mulled over by all members of the clinic.

Out of this unrestricted give-and-take, it is expected that the group may distill the rough outlines for at least two or three basic instrument research investigations. These will be followed up through grants by the Foundation, at appropriate institutions.



CONTINUOUS VACUUM FORMING of shapes in plastic sheets is featured in a new process by Quick Industries Inc. The sheet is taken directly from the extruder and, while still warm and soft, passed over a vacuum pattern roll where it is formed in the desired shape. Types of plastics treated include styrene, polyethylene, acetate and butyrate. Present equipment makes sheets 24 in. wide with thicknesses from 0.008-in. to more than 0.080-in. Process was developed originally to furnish an extended wetted deck surface for the air-conditioning and refrigeration industry.

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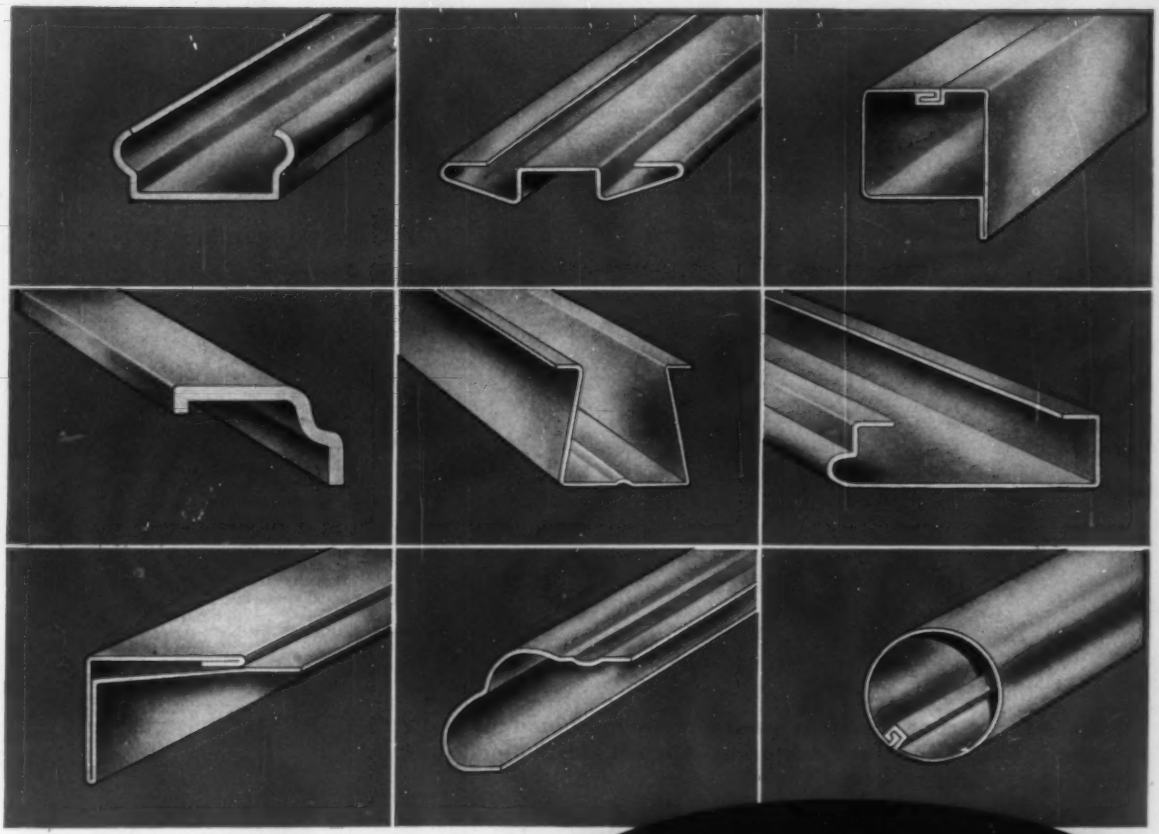

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Circle 408 on page 19

Cutting motions of the numerically controlled milling machine are monitored by instruments capable of detecting a motion as small as 0.0002-in.

New 50-Ton Milling Machine Guided By Tape, Not Jigs

Punched-tape control system result of more machined forgings, castings in airframe manufacturing. Aircraft, missile lead time cut substantially.

DETROIT, MICH.—The first production application of a system of numerically controlled milling was announced recently by the Martin Co. and Bendix Aviation Corp. Built for Martin by Bendix Research Laboratories, the system is the first for which a machine was specifically designed to operate at the speeds and feeds maintained by punched-tape control. Electronic equipment will translate coded blueprint information into three-dimensional cutting operations of a 50-ton milling machine. The new system will produce structural parts for TM-61 Matador tactical missiles and P6M Seamaster jet seaplanes.

Elements of design will be standardized for numerically controlled milling, and coded for storage in the system's memory unit. A call-out symbol or equation constant included in the numerical design of a part will then start machining operations. After a production run starts, engineering changes which become necessary will be incorporated by splicing in a new section of tape. Changeover from job to job will be as simple as replacing a reel of tape.

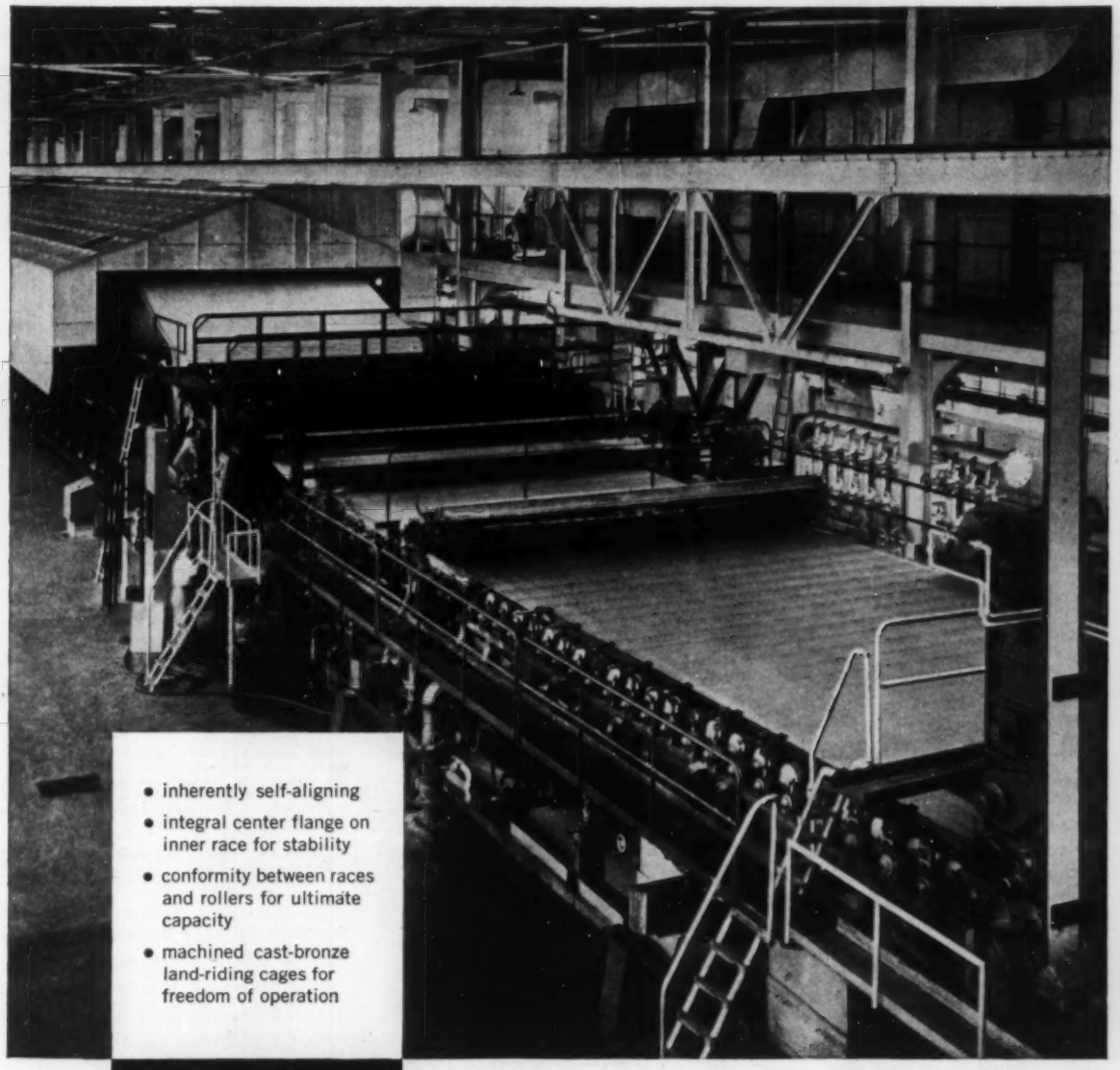
Drawings of parts selected for machining by numerical control will be modified to the extent of giving dimensions either perpendicular or parallel to a predetermined reference point on numerical drawings. These, together with feed rates, cutter radii, computer and milling machine instructions, will be compiled on process planning sheets. A special holding fixture in which clamps, locating surfaces and reference point are co-ordinated with the process planning sheet data is designed simultaneously. Flexowriters will then transfer process sheet data to punched paper tape to serve as the input medium to feed information to the computer. The computer will calculate machine commands and transfer them to plastic tape for machine control. Self-checking features in the tape preparation system will detect and correct errors in the process tapes. The machine control unit will detect errors in control tapes.

Machine Specifications

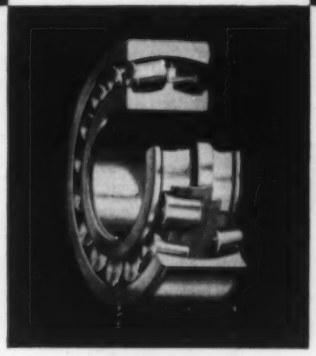
Working Surfaces:	
Horizontal table	60 x 120 in.
Vertical angle plate	48 x 144 in.
Range:	
Longitudinal travel of table	120 in.
Vertical travel of spindle saddle	48 in.
Transverse travel of spindle head	28 in.
Spindle:	
Speed range forward and reverse	36-1800 rpm
Number of speeds	16
Drive motor	20 hp
Feeds:	
Feed rate each axis	0-50 ipm
Rapid traverse	120 ipm
Cutter Coolant:	
Coolant system	Flood or mist
Capacity	100 gal
Manual Controls:	
Operator may adjust depth of cut and manually adjust tape controlled feed rate over the range from 25 to 125 per cent of nominal.	

The machine tool part of the new system has hydraulic servos of greater sensitivity than those in many missiles. The three cutting motions of the machine are monitored by feedback instruments capable of detecting motion as small as 0.0002-in. Precision gaging in the machine allows worn tools to be replaced without loss of accuracy between cutter and workpiece.

Martin officials termed the development of the new system "particularly timely," in reference to a statement made recently by Dudley C. Sharp, assistant secretary



- inherently self-aligning
- integral center flange on inner race for stability
- conformity between races and rollers for ultimate capacity
- machined cast-bronze land-riding cages for freedom of operation



A New World's Record!

World's record on 50# Kraft bag paper—2,200 fpm—is held by this 232-inch paper machine built by Beloit Iron Works for St. Regis Paper Company at Jacksonville, Florida.

Contributing to this performance are 718 Torrington Spherical Roller Bearings on wire rolls, press felt rolls, top press rolls, paper and felt driers and idlers, calenders, suction couch and press rolls, reels and winders. Inherently self-aligning, these bearings compensate for shaft deflection across the machine and eliminate need for periodic realignment.

Torrington Spherical Roller Bearings are available from stock with straight or tapered bores for shaft or adapter mounting. When you are counting on production, count on Torrington Spherical Roller Bearings for smoother, faster, more economical service from wet end to winder. *The Torrington Company,* South Bend 21, Ind.—and Torrington, Conn.

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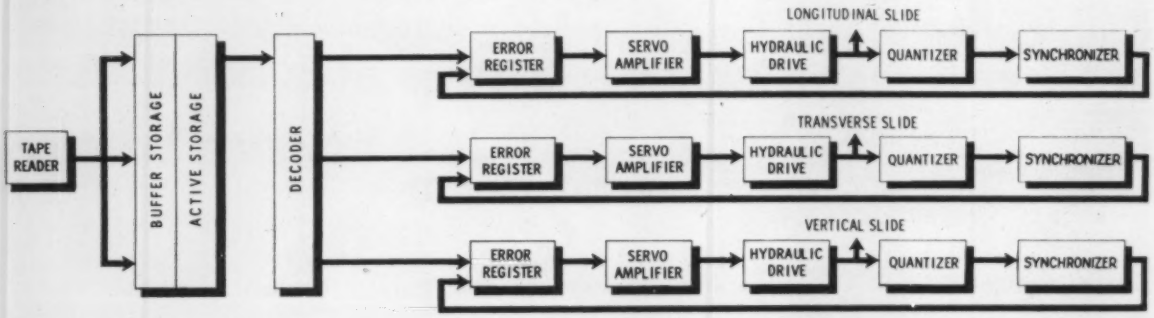
Circle 409 on page 19



Control unit elements read and process tape commands for translation into three-dimensional cutter action.

Tape Reader: A photoelectric reader senses holes in the tape. **Buffer Storage:** Receives one block of information from the control tape and stores it until required by the active storage section. **Active Storage:** Receives information from buffer storage and supplies it to the decoder as required. **Decoder:** Changes coded digital information on control tape to command pulses which serve as input to the machine-motion servos. **Error Register:** Keeps a running count of difference between the number of command pulses from the decoder and the number of feedback pulses from the quantizer on the machine. The error count is then converted to a proportional voltage. **Servoamplifier:** Receives and amplifies the proportional voltage from the error register. Its output drives the torque motor of the hydraulic servo valve. **Hydraulic Drive:** Each drive consists of a rotary hydraulic motor coupled to a lead screw through a low-backlash gear train. The lead screw drives the table, carriage or spindle by means of a ball bearing nut. **Quantizer:** Each axis has geared to it a quantizer which produces electrical signals as the axis moves. **Synchronizer:** Converts the signals from a quantizer into pulses—one pulse for each increment of travel. These pulses represent a feedback of a machine motion.

to the Air Force. He said that sizes, shapes and tolerances of airframe components "will demand increased automation and numerical control over machine operations." In the event of sudden mobilization orders, control tapes for many parts could be produced in a matter of hours and shipped to plants anywhere in the country that had similar electronically controlled milling machines.

Martin's decision to use numerically controlled milling was based on present trends toward greater use of machined forgings, castings and extrusions in airframe manufacturing. The tape-controlled process eliminates hand-made patterns, master parts, templates and models required for prototype aircraft and missile construction.

Example:

Assume that the following machine motions are desired:

Longitudinal motion,	$X = 0.1532$-in.
Transverse motion,	$Z = 0.0862$-in.
Vertical motion,	$Y = 0.0288$-in.

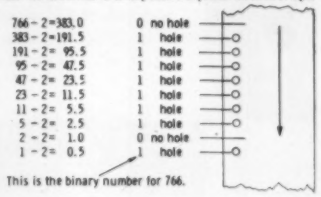
Since the basic machine unit of movement is 0.0002, the first step is to convert the desired increment of motion to machine units.

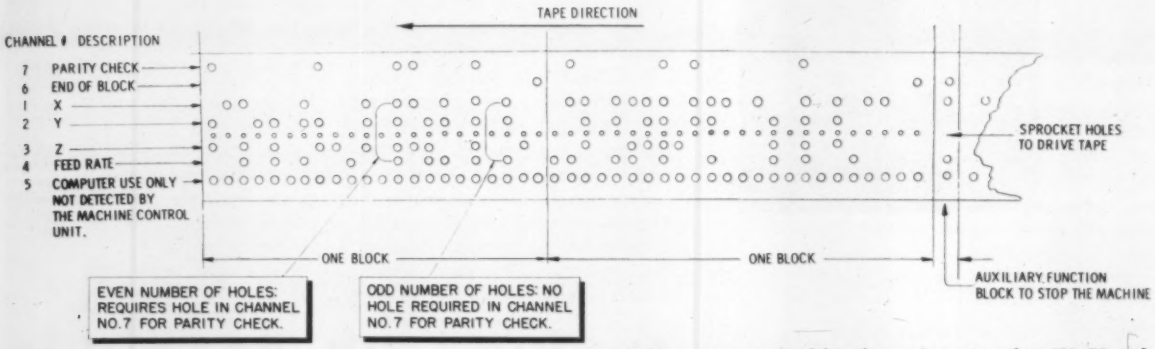
$X = 0.1532$	$0.0002 = 766$ units
$Y = 0.0862$	$0.0002 = 431$ units
$Z = 0.0288$	$0.0002 = 144$ units

These increments are punched on the tape in binary code which is simply a description of the number by using a series of ones and zeros. On the tape a punched hole represents a one and no hole represents a zero.

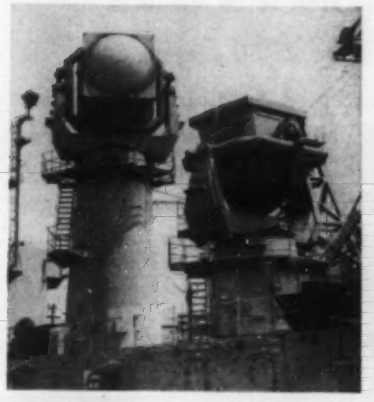
$X = 1011111110$ Binary number for 766 units
$Y = 0110101111$ Binary number for 431 units
$Z = 0010010000$ Binary number for 144 units

The number 766 converted to binary code and placed on control tape.




TAPE DIRECTION
CHANNEL # DESCRIPTION
7 PARITY CHECK
6 END OF BLOCK
1 X
2 Y
3 Z
4 FEED RATE
5 COMPUTER USE ONLY NOT DETECTED BY THE MACHINE CONTROL UNIT.
SPROCKET HOLES TO DRIVE TAPE
ONE BLOCK
ONE BLOCK
AUXILIARY FUNCTION BLOCK TO STOP THE MACHINE
EVEN NUMBER OF HOLES: REQUIRES HOLE IN CHANNEL NO.7 FOR PARITY CHECK.
ODD NUMBER OF HOLES: NO HOLE REQUIRED IN CHANNEL NO.7 FOR PARITY CHECK.

Control tape channels are identified by numbers, left. Longitudinal motion of the machine table, vertical motion of the spindle saddle and transverse motion of the spindle are controlled by channels 1, 2 and 3 (X, Y and Z axes) respectively. Channel 7 is punched when required to make the total number of holes in channels 1, 2, 3, 4, 6 and 7 of each line an odd number.



GUIDANCE FOR TERRIERS is performed by these massive radar antennas aboard the guided missile cruiser *Canberra*. The Navy now acknowledges their identity; reveals designation of SPQ-5. Developed by Sperry Gyroscope Co., the towers can be used alone or together to direct Terrier missiles to targets beyond the horizon.

Grinding Wheel Sizing, Shaping Continuous With New Process

Cemented Diamond Particles Seen Key to Grinding Automation

DETROIT, MICH.—Complete automation of production grinding is now possible with a process that eliminates time-out for wheel dressing and sizing. The process combines two developments: perpetual form control of grinding wheels and form cutters using cemented diamond particles in a powder metal cutter body.

Developed by Jones & Lamson Machine Co. and Koebel Diamond Tool Co., the process and equipment make possible production of several hundred thousand pieces without attending to the cutter-dresser. Wheel shapes and forms are produced and maintained with narrow dimensional limits. Present recommendations cover finishes down to 30 microinches rms.

Cemented diamond particle tools and cutters were developed to use diamond powder rather than large, whole diamonds of various sizes. Wheel dressing loads are distributed over many points. Dressing action is reproducible from cutter to

(*Continued on Page 22*)

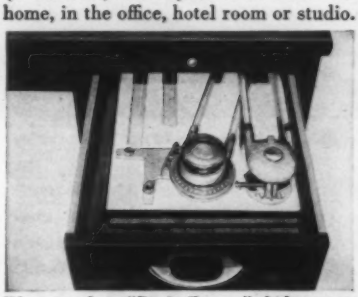
DRAFTING TRENDS

Chief Draftsman W. P. Nickels of Tennessee Gas Transmission Company (Houston, Texas) at work with his portable "Desk Topper"

Portable drafting unit sets up in two minutes

A handy drafting unit with the precision of a full-size drafting machine is now available to engineers who need portable facilities. Called "Desk Topper," the package-size unit can travel along with you or slip away in an office drawer. All essentials are included: drafting machine, set of scales, folding board, storage container for tools, and paper dispenser.

The "Desk Topper" sets up quickly (2 minutes) on any desk or table—at home, in the office, hotel room or studio.



The complete "Desk Topper" hides away quickly in any standard desk drawer or in the sturdy carrying carton. (Handsome luggage case is available at extra cost.)

The unit comes packed in a lightweight carrying carton for easy portability. For engineers who use the board only occasionally, the entire unit fits into any standard desk drawer.

Manufactured by Universal Drafting Machine Corp., "Desk Topper" has the professional features of their large "Boardmaster" machine—360° protractor, automatic 15° indexing, full line base selector, double 10′ vernier and clamp, elbow height adjustment, screw anchor, enclosed band and pulley arms, built-in brakes for 10° board slope.

The smooth linoleum surface board measures 21″ x 23½″ when open, 21″ x 11¾″ when closed. Normal drawing capacity is 17″ x 22″, or 24″ x 36″ when mounted to a larger board. The legs with rubber feet fold up automatically, provide a 10° slope in use.

The "Desk Topper" scales are another excellent feature. Self-locking and self-aligning, they eliminate two common causes of drafting machine inaccuracy —loose chucking, and errors in right angle alignment.

Further information on "Desk Topper" is available from the Reader Service Division of the Frederick Post Company, 3652 N. Avondale Avenue, Chicago 18.

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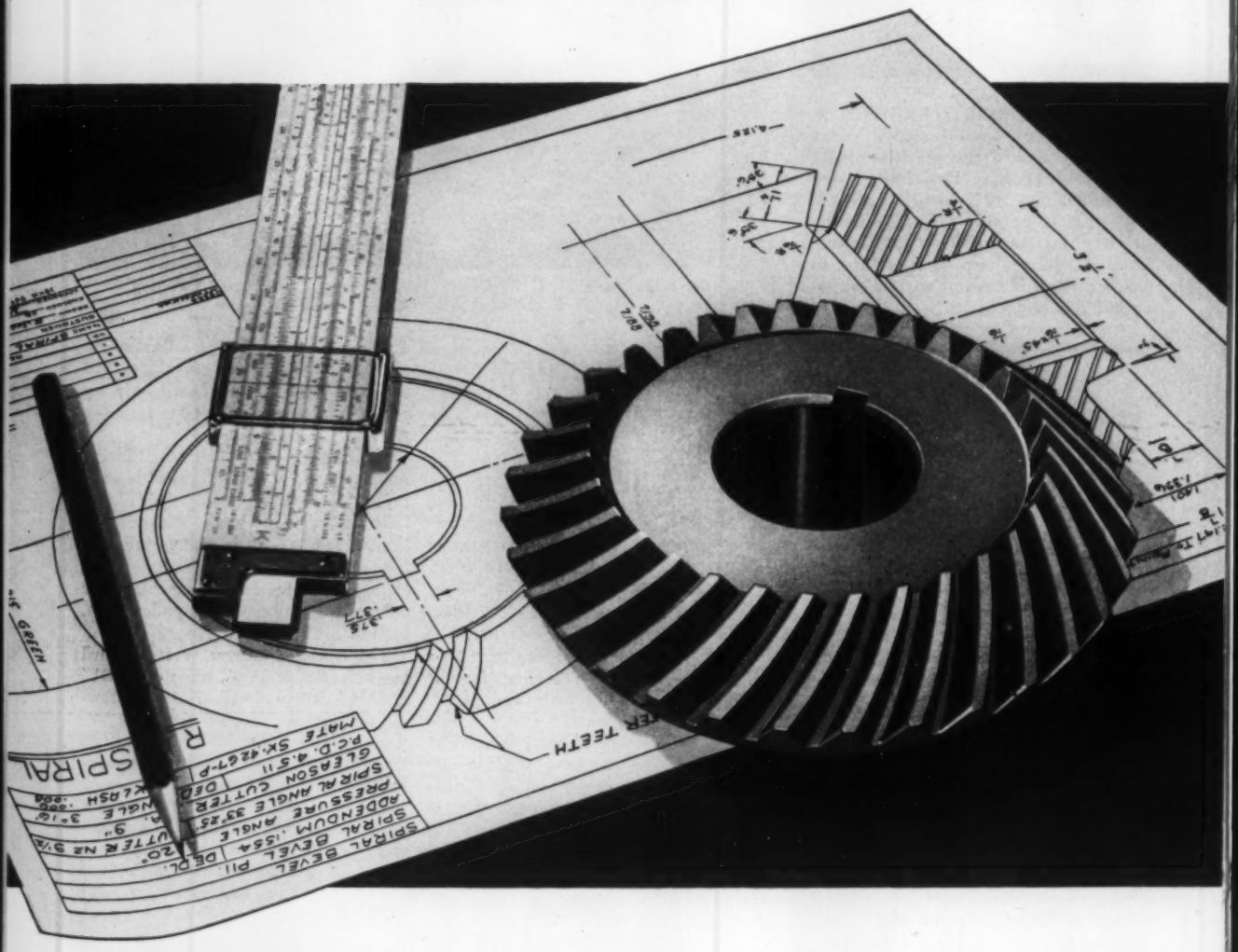
"ENGINEERED QUOTATIONS"

When our engineers study our customers' prints, they look for ways to improve gear performance, ways to simplify gear installations, ways to cut gear costs. When they find a way that they consider better they report it to the customer for his consideration. Very often these "engineered quotations" are accepted. Such careful scrutiny of every engineering and manufacturing step by *gear specialists* is one reason why so many manufacturers use Automotive Gear Division as their "gear department". May we submit an "engineered quotation" on your gear requirements?



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Reader Information Service

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CIRCLE ITEM NUMBERS—Throughout the magazine, each advertisement carries an Item Number for use in requesting further information. All product descriptions, announcements and Helpful Literature items are also numbered, and for greater convenience are indexed below by Item Numbers.

EDITORIAL CLIPSHEETS—So you won't have to "clip" this issue, we'll be glad to send a personal copy of any article as long as the supply lasts. Just fill in the page number and title of article in the place provided on the Yellow Card.

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CLEVELAND, OHIO

BUSINESS REPLY CARD
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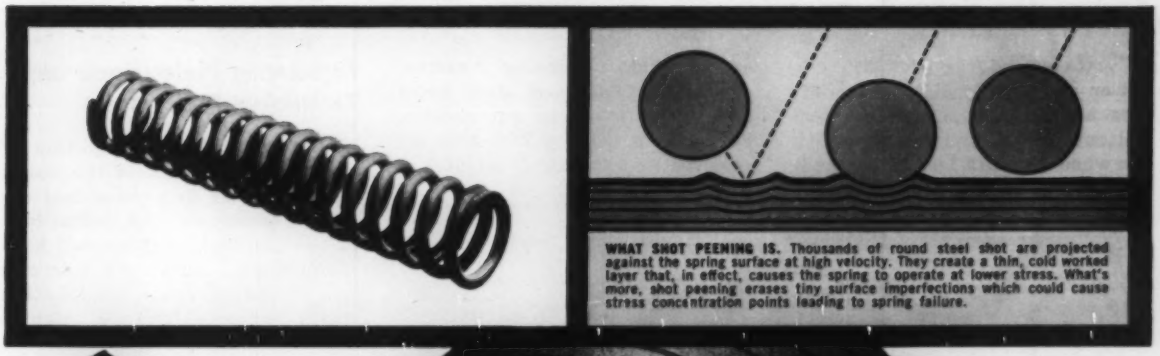
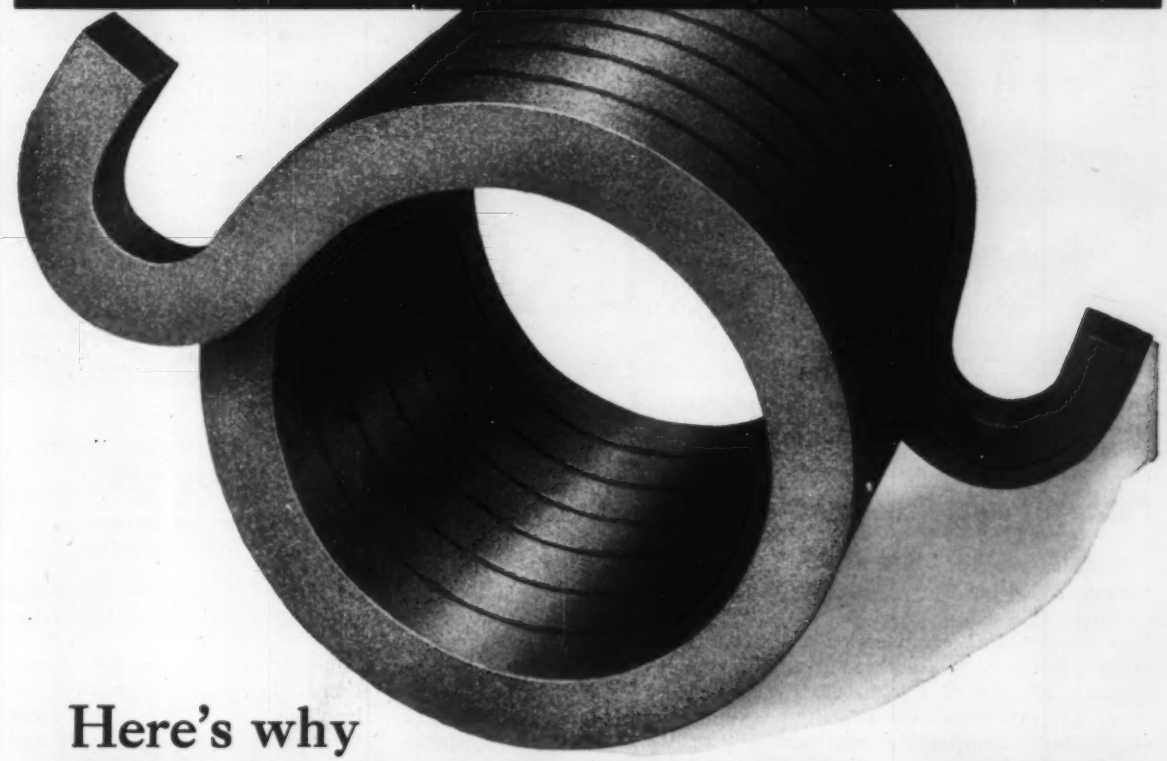


WHAT SHOT PEENING IS. Thousands of round steel shot are projected against the spring surface at high velocity. They create a thin, cold worked layer that, in effect, causes the spring to operate at lower stress. What's more, shot peening erases tiny surface imperfections which could cause stress concentration points leading to spring failure.



Here's why

CRUCIBLE FATIGUE RESISTANT SPRINGS

can withstand higher stresses

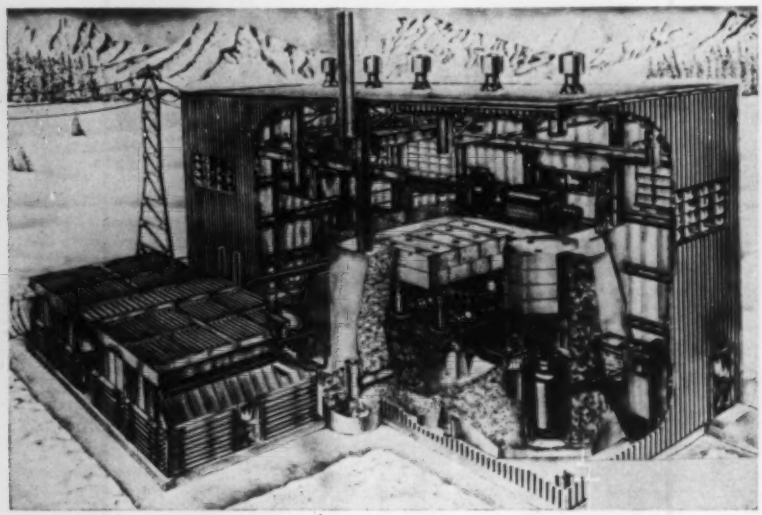
Every Crucible *fatigue resistant* spring for heavy-duty industrial applications is shot peened for higher strength and greater fatigue resistance. Crucible controlled shot peening imposes a negative stress on the surface that offsets positive stresses set up in service. Result: a truly *fatigue resistant* spring that outlasts conventional ones.

Good springs are a combination of proper design, skilled workmanship and fine steel. When you buy Crucible springs you employ a staff of proven designers and spring makers, and Crucible's years of experience in fine steel making—from ore to finished springs. Let an experienced Crucible spring specialist suggest the best *fatigue resistant* spring for your application. Or write for a copy of the "Handbook of Coil Spring Design." *Spring Division, Crucible Steel Company of America, McCandless Avenue, Pittsburgh 1, Pa.*

CRUCIBLE spring division

Crucible Steel Company of America

(*Continued from page* 15)
cutter and from tool to tool. Cutters are set to operate in intermittent or continuous contact with the wheel. Applications of the process include grinding narrow grooves in hardened steel parts for aircraft and automobiles. Forms $\frac{3}{8}$-in. deep by 2 in. wide are removed in less than 5 minutes.



First power reactor for the Army, in preliminary sketch, is also first integrated unit using pressurized water concept; first with stainless-clad fuel.

Package Power Reactor Developed For Remote Bases

Designed For Air Travel, Fast Set-Up

WASHINGTON, D.C.—Application of nuclear power to military requirements is the aim of a joint AEC-Army program to develop a family of reactors. Components will be transportable by air to remote military bases and erected in 6 months. These proposed features have resulted in the development of a 2035-kw capacity Army Package Power Reactor at Ft. Belvoir.

Built by Alco Products Inc., the APPR will begin a 700-hr performance test shortly. Plant output will eventually supplement Ft. Belvoir's power distribution system. It is the first complete integrated generating plant using the pressurized water concept and stainless steel-clad fuel, with light water as both coolant and moderator. Preliminary design studies of package reactors were made at Oak Ridge National Laboratory.

Design modifications for greater safety were necessary to adapt the APPR to permanent operation in its present populated section. A vapor container was designed to withstand the highly improbable maximum credible accident. Welded seams were 100 per cent radiographed and plates thicker than $1\frac{1}{2}$ in. were stress relieved after welding. A beam system with a maximum moment of 4.3 million lb ft and a shear of 400,000 lb resists reactor thrust in case of vessel rupture.

Three identical ion-chamber channels serve as detecting elements for neutron flux in a safety circuit. These "scram" the unit should power reach an unsafe level. Two of the three channels must agree that scramming is required to preclude a "scram happy" condition of operation.

Instrumentation is designed to permit an operator seated at the console to check all components. A 72-point annunciator pinpoints trouble spots, and interlocks take over when potentially dangerous situations begin to develop.

Engineering Professionals and Technicians Reject Union

MINNEAPOLIS, MINN.—Rejection of union representation is the result of an election by professional engineer employees and technicians at the Minneapolis-Honeywell Regulator Co. All parties and interests had conceded that the election would have nationwide significance. Here are the results:

Professional Employee Voting Group	
For United Auto Workers, AFL-CIO	304
For Engineers & Scientists of America	197
Neither (No union)	896
Technician Voting Group	
For UAW, AFL-CIO	254
For ESA	62
Neither (No union)	404

Returns indicate that 64 per cent of the professionals rejected unionization and that 56 per cent of the technicians voted the same way. On the preliminary question, for professionals only, whether they wished their ballots counted with those of the technicians, the vote was 974 No; 429 Yes.

Solid Rocket Fuels to Replace Liquid Type Eventually

Cost Savings Indicated In Missile Manufacture

NEW YORK, N.Y.—Solid propellants for rockets will soon duplicate the performance and total output of liquid fuels in the same applications. Liquid fuels, however, will be used for a long time to come because of superior accuracy and controllability.

These were recent remarks by Konrad K. Dannenberg of Redstone Arsenal. Mr. Dannenberg spoke at a recent meeting of the ASME.

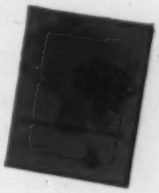
Another prediction by Mr. Dannenberg was that more powerful and efficient liquid fuel combinations will be used. The fuels will contain materials such as fluorine or fluorine compounds to be employed together with high energy fuels. "Hybrid" engines, using liquid oxidizers such as hydrogen peroxide, and solid fuels such as polyethylene, will comprise a promising new field.

In the field of producing rocket engines for use today, other speakers reported that efforts are being made to cut costs without diminish-

HAYNES investment casting solves the *tough* design problems

Investment Cast TURBINE BLADES Operate for thousands of hours above 1500 Deg. F

The age of supersonic aircraft has created a demand for intricately-shaped turbine blades that have excellent strength and low creep rates at high temperatures. Blades made of HAYNES Alloys meet these requirements and that is why they are used in the fastest gas turbine engines. To mass-produce these blades, HAYNES' investment-casting method has proven the economical answer. Compressor blades, vanes and other aircraft components are also efficiently produced by this modern method. For complete information, write for the booklet "HAYNES' Investment-Casting."



. . . Testing for soundness – Sample castings of every part produced are X-rayed, as part of the normal inspection procedures set up to insure top quality. This test helps to check foundry practices and also makes sure that the part will meet the necessary requirements for soundness.

HAYNES STELLITE COMPANY

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Why COST CONSCIOUS men are choosing Norgren MICRO·FOG

1. Better Lubrication — Less Machine Down Time

MICRO-FOG lubrication automatically coats all the bearings, gears, chains and other components of a machine with a continuous, protective film of clean oil. Just the right amount of oil is applied to provide the most efficient lubrication, reducing wear on machine components and cutting maintenance and replacements costs.

2. Oil Always Fresh, Always Clean

There is no recirculation of deteriorated or contaminated lubricant to cause wear or corrosion. Clean oil is applied continuously to all lubrication points in carefully metered amounts.

3. For Large and Small, Plain and Anti-Friction Bearings

MICRO-FOG Lubricating systems have found enthusiastic acceptance for use on all types of machinery, ranging from *high speed* grinders to huge roll mill bearings on shafts as large as 34" in diameter and turning at relatively *low speeds.*

4. Centralized, Automatic Lubrication

A single, MICRO-FOG Lubricator will automatically deliver enough airborne lubricant, proportionately distributed to completely lubricate even a large machine tool. Only one lubricator to maintain and refill.

5. Big Savings in Lubricant

Carefully metered quantities of oil are applied to each lubrication point. MICRO-FOG provides more thorough lubrication using only a few ounces of oil per day than other methods using several gallons of oil per day.

6. Bearings Run Cooler

Air passing through the bearing carries away heat, and there is no pool of lubricant in the bearing to generate heat as a result of fluid friction. Lubrication is continuous — there are no periods of insufficient lubrication with metal wearing on metal.

For Lubricating

- BEARINGS
- GEARS
- CHAINS
- SLIDES
- WAYS
- OTHER MACHINE COMPONENTS

7. Contaminants Excluded From Bearings

A slight positive pressure is maintained within the bearing, and air continuously escapes from the bearing, preventing the entrance of contaminants from the surrounding atmosphere.

8. Fewer Bearing Seals Required

Because MICRO-FOG must be vented to the atmosphere, it is not necessary to maintain tight seals. Fewer oil seals are required, reducing maintenance and machine down-time.

9. Oil Filters, Sumps and Pumps Eliminated

The quantity of lubricant used in MICRO-FOG Lubrication System is so small that there is nothing to reclaim or recirculate. Expensive high pressure piping is also eliminated.

10. Automatic Alarm Controls

MICRO-FOG Lubricators are available with switches to actuate an alarm system or controls as a warning of conditions affecting proper lubrication.

11. Visible Oil Feed

The oil feed is readily visible on all models of MICRO-FOG Lubricators, providing positive proof that the lubricator is operating properly.

12. A MICRO-FOG Lubricator For Every Size Machine

19 models to choose from—ratings up to 1,000 bearing inches and oil reservoir capacities up to 4½ gallons.

For complete information, call your nearby Norgren Representative, or WRITE FOR NEW 800 CATALOG.

C. A. NORGREN CO.

3442 SO. ELATI ST., ENGLEWOOD, COLORADO

Atom Angles

Synthesis of elements 102 and beyond may be possible with a new atom smasher, the most powerful of its kind, now in operation at the University of California. This was announced recently by the university and the Atomic Energy Commission. Named Hilac, the new machine is a heavy ion linear accelerator. It was designed specifically for study of the nine artificial elements beyond uranium.

Currently Hilac is accelerating nuclei of nitrogen atoms to energies of 140-million electron volts and is designed to handle the nuclei of atoms ranging up to argon 40. Unlike the university's more powerful bevatron, which accelerates hydrogen nuclei to 6.2-billion volts, Hilac will be concentrated on heavy particles. It may make possible the addition of large fragments of matter to target material, bringing about big jumps in the periodic table in single transmutations.

• • •

Serious shortage of domestic fuels in Western Europe may result in rapid development of competitively priced nuclear power in that area, according to the U.S. Atomic Energy Commission. An immediate program calling for an initial fuel inventory costing $1.7 billion has been proposed to the AEC by Euratom, Western Europe atomic energy agency. Longer range plans anticipate that 15-million kw capacity must be in operation by 1967.

In return for technical and material assistance, this country would receive knowledge of cost and operating details. The AEC declares a need in many other parts of the world for nuclear power in small installations ranging from 5000 to 10,000-kw capacity and the necessity for the U.S. to solicit this nuclear power business abroad.

First sodium-cooled "thermal" reactor has been developed for the AEC by Atomics International Div. of North American Aviation Inc. The Sodium Reactor Experiment (SRE) is a small-scale experimental civilian atomic power project. The SRE uses neutrons moderated with graphite to sustain fission, and liquid sodium is circulated through the reactor core to remove heat.

During the initial test, the reactor operated at a power level of about 1 kw of heat. No electricity was generated. The design capacity of SRE is 20,000 kw of heat. Following tests, the heat will be purchased by Southern California Edison Co. to generate 6500 kw of electricity on an experimental basis.

• • •

Gamma ray control for molten titanium is featured in a new electric furnace accessory. Used to measure the liquid level of melt in the furnace, this control developed by Westinghouse Research Laboratories operates with titanium at 3000 F. It may be applicable to other types of furnaces and in other measuring and leveling processes.

The amount of gamma radiation passing through the furnace depends upon the level of melt inside. Changes in radiation are used to detect and correct the liquid level. Rays are detected by two scintillation counters. This type of counter changes the rays into flashes of light, then converts the light flashes into electrical pulses and amplifies them. The pulses are fed to electronic circuits which activate a hydraulic system that raises or lowers the ingot to the exact position required for proper operation of the furnace. Position is maintained to within 0.01-in., and the control will cause immediate shutdown if the ingot moves beyond prescribed limits.

ing performance. They pointed out that since most rocket engines are used by the military, the prime objectives today are reliability and safety during use rather than low cost.

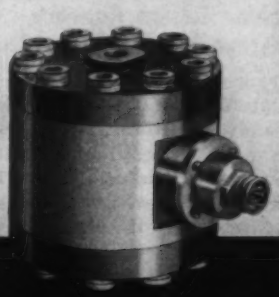
In addition to attitudes that rate costs secondary, factors contributing to costs are the pressures of time, the intricacy of the devices, a relatively low production rate and the fact that changes in design may occur at any time. Despite these, however, examples can be cited of

MODELS PL80 AND PM80

Differential Pressure Transducers

FOR

flow measurement



AT

Rocket Engine Stands
Hydraulic System Tests
Nuclear Reactors

the flow of liquids and gases is being measured by connecting Model PL80 and Model PM80 pressure transducers across an orifice.

Ranges
±1 to ±3000 psid and 0-1 to 0-3000 psid

Line Pressure Rating
5000 psig

Pressure Media
Fluids not corrosive to Types 303 and 347 stainless steel

Transduction
Resistive, Statham unbonded strain gage

For additional data, please request Bulletin Nos. PL80TC and PM80TC

Statham
LABORATORIES
12401 W. Olympic Blvd., Los Angeles 64, Calif.

Circle 415 on page 19

dollars saved through improved production engineering techniques.

One such cost-saving step involved the welding of a steel bar in the nozzles of Honest John rocket motors to prevent them from bending excessively during use. This permits economical re-use of certain parts at a saving of $75,000 per year. In another case, hot-rolled and flash-welded parts were substituted for certain forgings in the Nike missile booster. Engineers saved $10,000 per unit.

Machine Design Appoints Assistant Editor

Francis A. Husarik has joined the staff of MACHINE DESIGN as an assistant editor. Mr. Husarik received his education at the College of St. Bernadine of Siena, Loudonville, N.Y., where he majored in mathematics. He was previously associated with the Research Div.

Francis A. Husarik

of United Aircraft Corp., East Hartford, Conn., as assistant to project engineer in aerodynamic research; with Pioneer Parachute Co., Manchester, Conn., as systems recovery engineer; and with the Hamilton Standard Div. of United Aircraft Corp., Windsor Locks, Conn., in development and test engineering and as a training instructor. Mr. Husarik has been assigned responsibility for several feature departments of MACHINE DESIGN.

Engineering Center Building To Be Built in Cleveland

CLEVELAND, O.—Construction of a $1,525,000 Cleveland Engineering and Scientific Center has begun at 3100 Chester Ave. in downtown Cleveland. The new headquarters will be used by more than 50 engineering and technical groups and will provide a center for continuing technical education. The Cleveland Engineering Society, owner and operator of the building, expects occupancy during the summer of 1958.

The new building will be a two-and-a-half story structure with a five-story tower and will have approximately 50,000 sq ft of floor space. Facilities will include an auditorium seating approximately 900; a single-purpose, slanted floor auditorium to accommodate 150 people; a main dining room serving 350; three special dining rooms and class rooms. Exhibition area will accommodate heavy machinery and equipment.

Meetings

AND EXPOSITIONS

June 13-14—

Malleable Founders' Society. Annual Meeting to be held at the Broadmoor Hotel, Colorado Springs, Colo. Additional information is available from society headquarters, 1800 Union Commerce Bldg., Cleveland 14, O.

June 13-15—

Instrument Society of America. Third National Symposium on Instrumental Methods of Analysis to be held at the University of Chicago. Additional information is available from ISA headquarters, 313 Sixth Ave., Pittsburgh 22, Pa.

June 13-15—

American Society of Mechanical Engineers. Applied Mechanics Conference to be held at the University of California, Berkeley. Further information is available from ASME headquarters, 29 W. 39th St., New York 18, N.Y.

June 16-20—

American Electroplaters' Society. Annual Meeting to be held at Sheraton-Mt. Royal Hotel, Montreal, P. Q. Further information can be obtained from society headquarters, 445 Broad St., Newark, N. J.

June 16-21—

American Society for Testing Materials. 60th Annual Meeting to be held at Chalfonte-Haddon Hall, Atlantic City, N. J. Further information is available from society headquarters, 1916 Race St., Philadelphia 3, Pa.

June 17-20—

Institute of the Aeronautical Sciences. National Summer Meeting to be held at the Biltmore Hotel, Los Angeles. Further information can be obtained from institute headquarters, 2 E. 64th St., New York 21, N. Y.

June 17-21—

American Society for Engineering Education. Annual Meeting to be held at Cornell University, Ithaca, N. Y. Additional information can be obtained from society secretary, W. Leighton Collins, University of Illinois, Urbana, Ill.

June 19-22—

Drop Forging Association. Annual Meeting to be held at Grand Hotel, Mackinac Island, Mich. Additional information can be obtained from the association, 419 S. Walnut St., Lansing 33, Mich.

June 23-25—

Alloy Casting Institute. Annual Meeting to be held at the Homestead, Hot Springs, Va. Additional information is available from institute headquarters, 32 Third Ave., Mineola, N. Y.

June 24-28—

American Institute of Electrical Engineers. Summer General Meeting to be held at Sheraton-Mt. Royal Hotel, Montreal, P. Q. Further information is available from institute headquarters, 33 W. 39th St., New York 18, N. Y.

Design data on adhesives

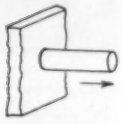
Armstrong
ADHESIVES • COATINGS • SEALERS

NUMBER TWO

Strengthening a common angle joint

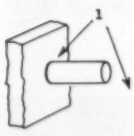
In redesigning a common angle joint (or any other ordinary joint) to give maximum strength with adhesives, four basic rules must be kept in mind.

1. Make the bonded area as large as possible.
2. Make the maximum proportion of bonded area contribute to strength.
3. Stress the adhesive in the direction of its maximum strength.
4. Minimize stress in the direction in which the adhesive is weakest.



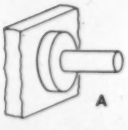
Here's how these rules can be applied: If the load is in the direction of the arrow, then stress distribution will yield high strength.

If the load is not exactly at right angles to the plane of the joint, the result will be a concentration of stress, a cleavage force (in this case at 1).



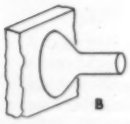
REMEDY

A. Increase area (better)



Bonded area has been made as large as possible. (Rule 1) Maximum proportion of bonded area now contributes to strength. (Rule 2)

B. Increase area and reduce stiffness at edge of joint (best)



Bonded area has been made as large as possible. (Rule 1) Maximum proportion of bonded area now contributes to strength. (Rule 2) Stress is now minimized in the direction in which the adhesive is weakest. (Rule 4)

If you have a design problem involving adhesive bonding, we may be able to suggest a practical, economical solution based on our 36 years of experience in making and using adhesives, coatings, and sealers. Send details of your problem to Armstrong Cork Company, Industrial Div., 8005 Dean St., Lancaster, Pa.

How to prepare surfaces for bonding

To attain optimum results with adhesives, the surfaces of the materials to be bonded must be clean. The amount of surface preparation necessary may be influenced by the type of adhesive used or the ultimate requirements of the bond.

Nonstructural adhesives, such as the pressure-sensitive or contact types, rubber cements, and asphalt adhesives, perform satisfactorily if the surface is free of dust and dirt, grease and oil, loose scale and corrosion products.

Where high-strength bonds are required, surface preparation must be more thorough. Chemical cleaning is preferred where the size of the production operation warrants installation of the proper equipment. Mechanical methods are desirable on operations where the number of assemblies to be bonded is small or where chemical cleaning would cause deterioration of part of the assembly.

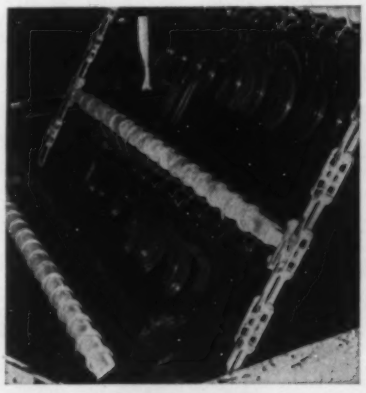


PHOTO COURTESY CHEVROLET-DETROIT GEAR AND AXLE DIV., GENERAL MOTORS CORP.

Before bonding, brake shoes are washed and pickled, then immersed in varnish dip and dried.

Listed below are typical procedures for cleaning materials frequently fastened by adhesives.

Aluminum may be cleaned with acidic or alkaline cleaners. Preferred alkaline cleaner of sodium metasilicate and a wetting agent in water at a temperature of 160° to 180° F. cleans aluminum in 4 to 5 minutes. Aluminum should be immediately rinsed with water. (A chromic acid rinse after alkaline cleaning prevents corrosion by residual alkali.)

Cleaning methods for spot welding are satisfactory for bonding. Preferable acidic cleaner consists of a solution of sulphuric acid and sodium dichromate at 140° to 160° F.

Steel should be free of rust and mill scale as well as dirt and grease. Use an alkaline cleaner to remove grease and dirt and follow with an acid pickling operataion. (Pickling of high-carbon steel and certain alloys often leaves a smut or residue which may be removed mechanically while wet or chemically with oxidizing agents.) Clean steel parts should be coated immediately to prevent rust formation.

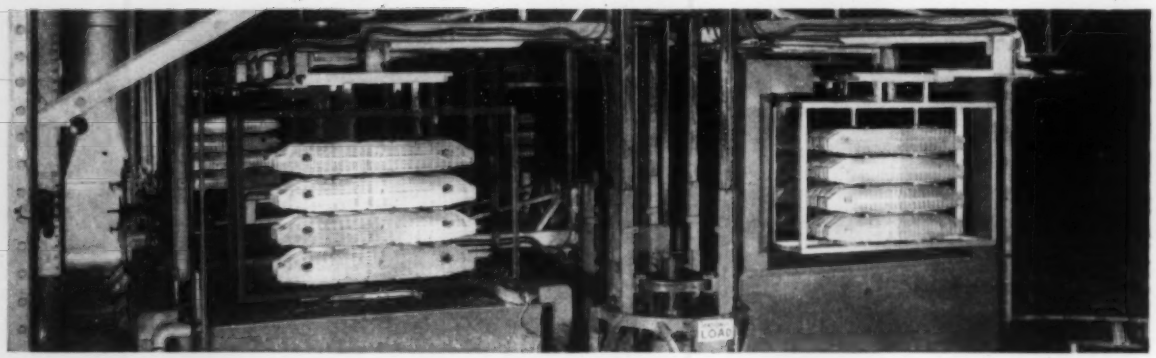
Magnesium may be cleaned by brushing lightly with a fine wire brush followed by hot alkaline cleaner and water rinse, or by anodizing. Magnesium supplied with conventional surface treatments sometimes can be used as is, but surface contamination should be removed with solvent. Common practice in the aircraft industry, for example, is to clean the metal, apply coat of zinc-chromate primer, and bond right over it.

Plastics should be sanded prior to bonding to remove mold finish and mold release agents. Flexible vinyl plastic sheets normally require no cleaning other than surface dirt removal. Other plastics may be wiped with a solvent; however, true solvents for the plastic normally should not be used as they may cause distortion, excessive softening, crazing and cracking.

Vulcanized Rubber parts are often contaminated with mold release agents or by plasticizer or wax exudation. Silicone mold release agents prevent good bonds, as the silicone greatly impairs adhesion to the rubber. Remove talc and water-soluble mold-release agents by washing with water; plasticizer and wax, by washing with solvent. Solvent used depends on the specific rubber; toluol generally is satisfactory, but it should be used with care, since it attacks some types of rubber. Light abrasion of the rubber surface improves adhesion.

Circle 416 on page 19

Parts for the products *you design* can be economically fabricated and here are 7

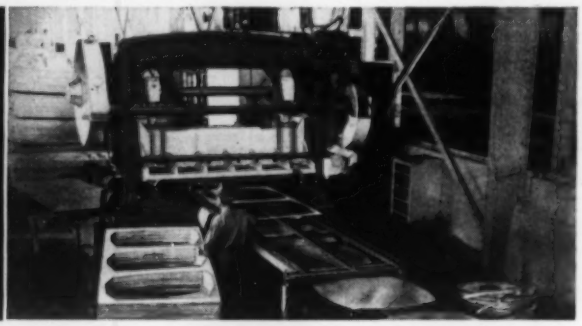


1 Reynolds ADDS TO YOUR CAPACITY WITHOUT INCREASING COSTS

Reynolds great variety of specialized equipment assures you the economy of the equipment best suited to your purpose. This can save you important capital investments in equipment and added plant capacity. The new Reynolds automatic aluminum finishing system above—shown gold anodizing automobile grilles—can finish mixed sizes and types of parts and chemically brighten or anodize them in different colors—and can handle several different jobs at the same time. An automatic coding system establishes the individual finishing specifications for each job.

2 Reynolds CUTS YOUR MATERIAL HANDLING COSTS

Reynolds assembling of the aluminum siding panels for truck subassemblies above is saving money for a truck-trailer manufacturer. Whether you make telephone booths, portable TV cabinets or a host of other products, you'll cut your handling costs by getting parts from Reynolds. Reynolds also takes the problems of scheduling, material supply, labor and machine availability off your hands.



3 Reynolds CUTS YOUR SCRAP LOSS AND HANDLING COSTS

The aluminum blanks on the conveyor are ready to go to an appliance manufacturer. The scrap beside the press is remelted immediately right at the Reynolds plant. Thus Reynolds Aluminum Fabricating Service saves you—the manufacturer—an average of 30% scrap loss and also eliminates costly time and labor scrap handling expense on your part in sorting, storing and shipping.

For details on Reynolds fabricating and finishing facilities write for your copy of Reynolds "Complete Facilities" brochure. And for the assistance of Reynolds Styling and Engineering Service, contact your nearest Reynolds Office or write to the address on the facing page.

The Finest Products Made with Aluminum are made with REYNOLDS ALUMINUM

finished by Reynolds

good reasons why

4 Reynolds REDUCES YOUR RAW MATERIAL INVENTORY

You get *pounds of parts* instead of pounds of metal when you use Reynolds Aluminum Fabricating Service. Like the manufacturer who will receive the parts in work on these high speed coil fed presses, you too can save by cutting out that costly part of your metal inventory that does not go into finished parts.

5 Reynolds RELEASES YOUR VALUABLE FLOOR SPACE

Equipment such as Reynolds new high speed buffing machines above, plus stocks of raw materials, take up valuable floor space. Imagine the space you can save in your plant—space you can put to profitable use—when you rely on Reynolds to produce quality aluminum components for your products.

6 Reynolds OFFERS YOU DELAYED MATERIAL BILLING

You receive 100% of your aluminum in finished parts when you use Reynolds Aluminum Fabricating Service. And, as these parts are generally billed after assembly into finished products, no investment is tied up in raw metal. Roll forming machines are but one example of the more than 200 pieces of major fabricating and finishing equipment offered by Reynolds in two plants alone.

7 Reynolds ELIMINATES YOUR REJECT COSTS

Reynolds Aluminum Fabricating Service does away with your machine and labor production losses and inspection expense in rejects, because you pay only for finished, inspected parts. The conveyor line above, where finished aluminum parts are carefully inspected before packing and shipping, is just one of the many examples of Reynolds quality control from mine to finished part.

See "CIRCUS BOY", Reynolds exciting dramatic series, Sundays, NBC-TV

REYNOLDS ALUMINUM FABRICATING SERVICE

2061 South Ninth Street, Louisville 1, Kentucky

BLANKING • EMBOSSING
STAMPING • DRAWING
RIVETING • FORMING
ROLL SHAPING • TUBE
BENDING • WELDING
BRAZING • FINISHING

Circle 417 on page 19

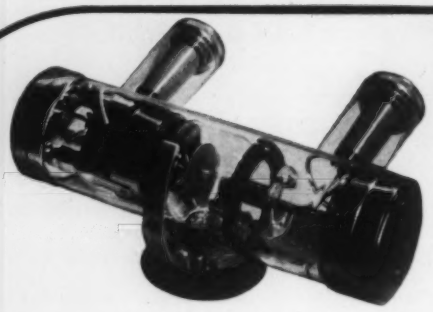
NICE BEARINGS
Help Advance
X-RAY DESIGN

Modern techniques in radio-graphic practice have placed new demands on X-ray tube capacity. These demands have been answered by Machlett Laboratories, Inc., Springdale, Connecticut, by the introduction of their DYNAMAX design. The Machlett DYNAMAX design incorporates a rotating anode mounted on highly specialized ball bearings made by NICE BALL BEARING COMPANY.

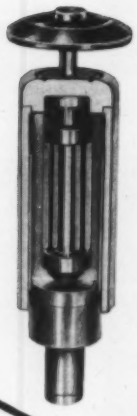
The commercial success of the rotating anode principle is largely due to the development of suitable bearings. The NICE bearings used by Machlett have proven to be the complete answer to all requirement problems. They are made to exacting tolerances from special heat resisting steel and are silver lubricated for use in high vacuum.*

Now Available! New NICE Cat. No. 190

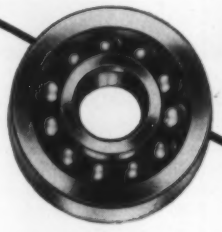
*Machlett U. S. Patent No. 2,315,280



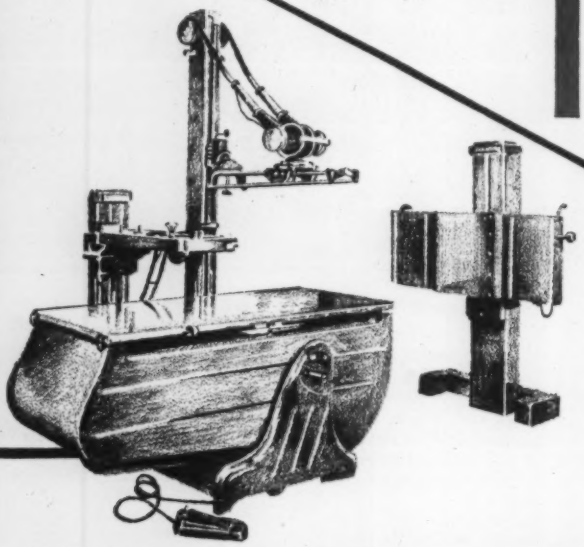
Machlett DYNAMAX "25" Rotating Anode X-RAY Tube (with plastic display case)



Cutaway View of Ball Bearing Mounted Rotating Anode and Motor Armature Core



Special NICE Bearing used at bottom of Rotor. A similar Special Bearing is mounted at top of Rotor.



Picker X-Ray Corporation Table and Tube-stand incorporating Machlett DYNAMAX

NICE is the word for **BEARINGS**

NICE

NICE BALL BEARING COMPANY
NICETOWN · PHILADELPHIA · PENNSYLVANIA

Circle 418 on page 19

WINZELER NOW STAMPS BETTER GEARING FROM 8 TO 120 DP!

SEE .018 INCH DIAMETER HOLE STAMPED IN MAGNIFIED IMAGE OF .032 INCH FACE, 120 DP BRASS GEAR.

The range of WINZELER *Stamped* Gearing has been increased. You can now get sizes ranging from 8 to *120 dp!* No matter what the size, or whether you need thousands or millions, you can expect the same remarkable accuracy and top quality in *every piece we ship.*

The outstanding success of WINZELER *Stamped* Gearing results from vastly improved methods of Tooling, Stamping, Assembling and Inspection. Mechanisms run smoother, quieter, longer. Production flows faster. Savings, up to 60%, are common. Ask us now about the Gearing you need. Send drawings or descriptions. Ideas, suggestions, low cost estimates do not obligate you. Write TODAY!

ACCURATE, LOW COST STAMPED BAKELITE GEARING

Now, WINZELER successfully *Stamps* and shaves with special tooling, Gearing from BAKELITE material up to 1/8" thick. Sizes, from 8 to 16 dp. Teeth are sharp, clean-cut, uniformly accurate. CUT COSTS. Check up on these tough, quiet, lightweight Gears today.

WINZELER *Stamped Gears*

MAIL THE COUPON FOR FREE STAMPED GEAR FOLDER

WINZELER MANUFACTURING & TOOL CO.,
7355 W. WILSON AVENUE, CHICAGO 31, ILLINOIS

Gentlemen:

Please mail to me, at once, a copy of the free WINZELER Stamped Gear folder.

NAME_____

COMPANY_____

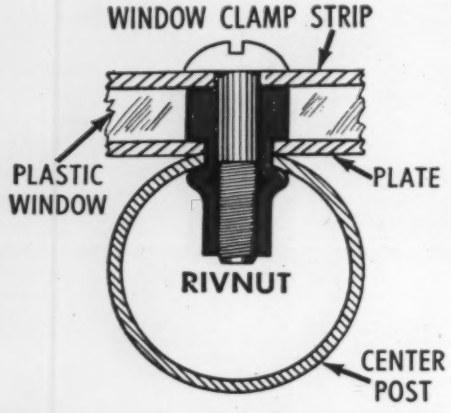
ADDRESS_____

CITY_____ ZONE____ STATE_____

Circle 419 on page 19

B.F.Goodrich Rivnut

provides blind nutplate so solid it's a shockproof seal

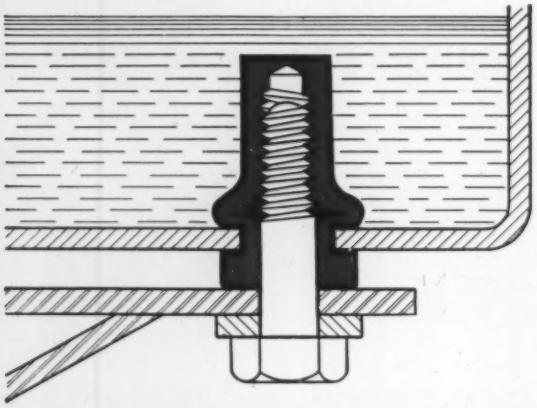


Here's a tough fastening problem that puzzled designers of airplane windows. They needed a nutplate and a blind rivet solid enough to serve as a shockproof seal. One B. F. Goodrich Rivnut solved the problem by performing all three jobs in one operation.

In seconds, one man upsets the Rivnut, securely rivets the plate to center post. The firm bulge in the Rivnut shank conforms to the curvature of the tube, giving a shockproof seal that keeps weather out. Rivnut head serves as spacer for plastic window, and provides 6 clean, firm threads that hold clamp strip and window securely in place.

Best of all, Rivnuts cut costs by reducing assembly time. Here's a typical example:

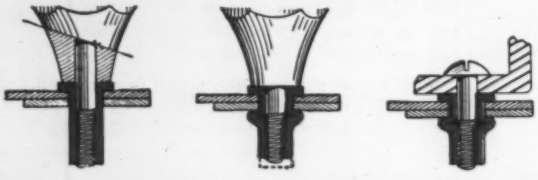
RIVNUT cuts fastening time 90% by eliminating brazing and tapping



A manufacturer of industrial oilers was brazing nutplates on his reservoir tanks for bolting to brackets. This required three separate operations—brazing, tapping, and thread cleaning. Too often, brazing caused warping and leaks. In addition, he had to fuss with bolts and washers to maintain proper shim space.

By switching to Rivnuts, he reduced all three steps to one quick operation. Rivnuts cut assembly time 90%, assured uniform quality in every product. Rivnuts can work wonders for you, too. Call on us for engineering help, or:

HOW RIVNUTS PROVIDE AT LEAST 6 CLEAN THREADS IN ONE SIMPLE OPERATION:



1 Rivnut is threaded onto pull-up stud of heading tool, then inserted.

2 Tool lever operates pull-up stud forming a bulge in the Rivnut shank.

3 After upset, Rivnut threads are still clean and intact, ready for screw attachment.

SEND NOW FOR FREE RIVNUT DEMONSTRATOR

Demonstrates with motion how Rivnuts fasten *to* and *with*. Explains construction, gives proved applications. Write to *B. F. Goodrich Rivnuts, Dept. MD-5B, Akron, Ohio.*

B.F.Goodrich

AVIATION PRODUCTS

a division of The B. F. Goodrich Company, Akron, Ohio

J&L cold drawn ELECTRICWELD tubing with a superior SPECIAL SMOOTH I.D. finish

Cold drawn ELECTRICWELD tubing with the superior smooth I.D. finish will cut your production costs in applications like these:

- **cylinder tubing**
- **hydraulic and pressure tubing**
- **shock absorbers**
- **ordnance components**

This new drawn-over-mandrel grade tubing with its mirror-like surface finish helps reduce or eliminate costly machining on many applications. For example, it may be used, without inside honing, for many cylinders through which plungers are passed.

ELECTRICWELD tubing withstands high internal hydrostatic pressures; carries heavy torsion loads; resists high-frequency vibration. It offers a favorable weight-to-strength ratio where loading occurs in all directions.

It is furnished in OD sizes from ½ inch to 2⅞ inches and in wall thickness from 20 to 10 gauge, 0.035 and 0.134 inch. Send coupon today for complete information.

Jones & Laughlin Steel Corporation
Dept. 410, 3 Gateway Center
Pittsburgh 30, Pennsylvania

Send me a copy of your cold drawn ELECTRICWELD tubing booklet.

Name_____

Title_____

Company_____

Address_____

City_____ Zone___ State____

J&L STEEL

Jones & Laughlin

. . . a great name in steel

Circle 421 on page 19

RED JACKET MANUFACTURING CO.
"jet pumps cost less to ship"

LENNOX INDUSTRIES INC.
"we just install them and forget them"

W. M. WELCH MFG. COMPANY
"eliminated heavy mounting frames"

K & S MANUFACTURING COMPANY
"stands up under roughest handling"

ANTHONY MACHINE & ENG. SERVICE
"*only* motor versatile enough for us"

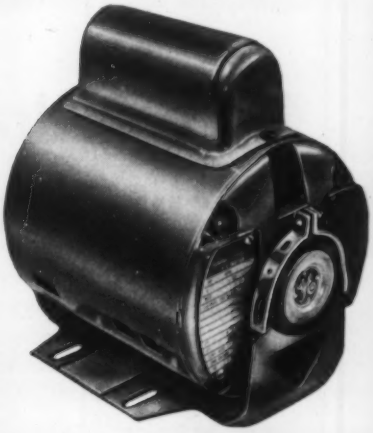
THE TRANE COMPANY
"reduced product weight nearly 8 lbs."

RUTHMAN MACHINERY COMPANY
"more compact, yet full-powered"

GE

Years Ahead

MOTOR



ALBERTSON & CO.—SIOUX TOOLS
"lighter, smaller—with power to spare"

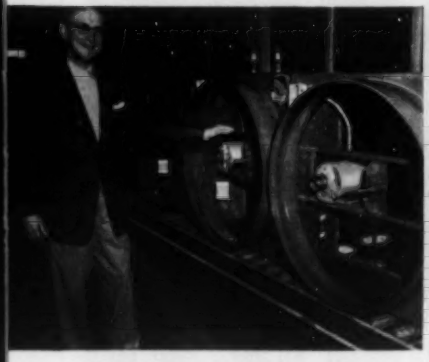
MODINE MANUFACTURING COMPANY
"dependable—in operation *and* delivery"

BARBER-COLMAN COMPANY
"cut manufacturing costs 12½%"

AUTO-NAILER COMPANY
"All-angle mounting cuts design costs"

G. C. BREIDERT COMPANY
"as quiet as it is dependable"

LANCASTER PUMP & MFG. CO.
"G-E motors help sell our pumps"



BAR-BROOK MFG. COMPANY
" 'no re-oiling' feature rates high"

SOUTH BEND LATHE COMPANY
"top quality at competitive prices"

TEMCO, INC.
"light weight cut shipping costs"

16 More Companies Say...

LESS COSTS, MORE SALES with General Electric fhp motors

Yes—16 *more* manufacturers, like yourself, have reported on the cost-savings and sales-increases they've realized by incorporating General Electric "Years-ahead" motors into their products.

They are representative of the thousands of companies who have realized similar benefits—adequate proof that this General Electric fhp motor *can* save you money—*can* make your product more saleable.

And no wonder! The G-E "Years-ahead" motor incorporates a number of advanced design features to give you longer motor life, unsurpassed versatility, and a lighter, smaller, more streamlined design to match your own modern product . . . for example—moisture resistant Mylar* polyester film insulation; dependable, all-angle sleeve bearings; doubled lubrication life; removable, rotatable cradle base; and many others.

To find out how you can take greater advantage of these G-E motor benefits in your own product, contact your nearby General Electric Apparatus Sales Office, or write to General Electric Company, Section 702-30, Schenectady, N. Y.

*Registered trade-mark of Du Pont Company.

GENERAL ELECTRIC

Circle 422 on page 19

FAST, HAMMER-DRIVEN RIVET ECONOMICAL FOR BLIND AND OPEN APPLICATIONS

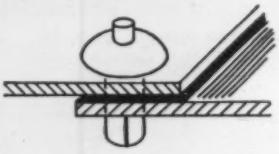


Fig. 1 Inserted in hole, Southco Rivets are quickly set by driving pin with hammer. No special tools are required. Bucking is not necessary.

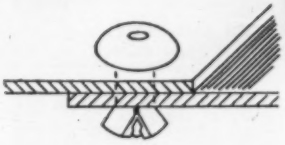


Fig. 2 Expanded prongs force sheets or parts together, hold them tightly in compression. No metal is removed, no grinding or finishing is required.

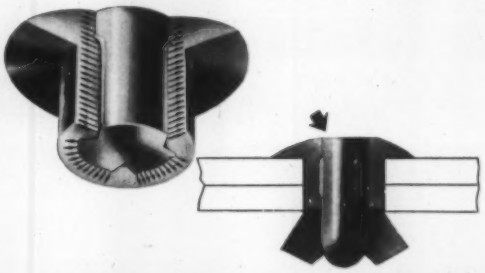


Fig. 3 Pin is locked securely into rivet by displaced metal filling unique grooves. Compression forces are utilized for greater strength.

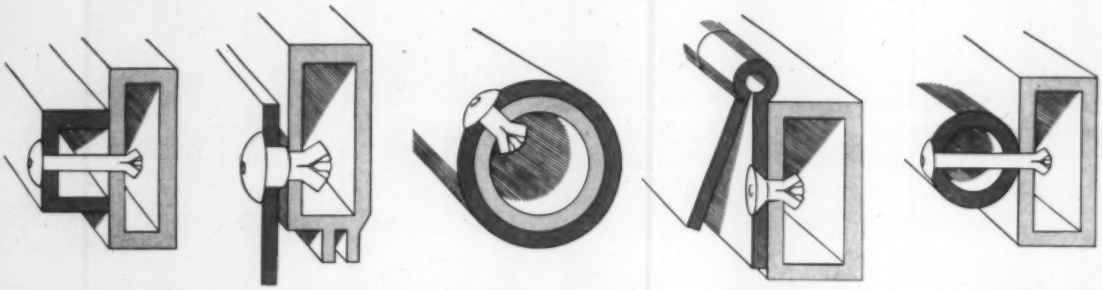


Fig. 4 Ideally suited for "blind" applications, Southco Rivets are worked by one man from one side only and require minimum space inside closed area. They eliminate costly bucking arrangement or time-consuming finishing. Supplied as a unit, they require no job time for assembly or fitting.

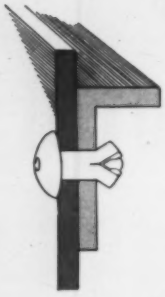


Fig. 5 Access or open fastening utilizes the simplicity, speed and vibration-resistance of Southco Rivets.

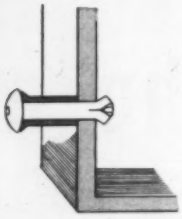


Fig. 6 Ferrules are used as spacers for numerous applications. Here the Southco Rivet forms a drawer pull in conjunction with a flanged tube.

Fig. 7 Increased head size distributes holding pressure over larger area, permits higher loading on wood, plastics and similar materials.

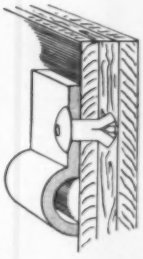
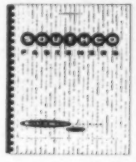


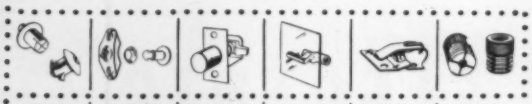
Fig. 8 A blind head can be formed inside the wood. This application is particularly useful when it is desirable to have one surface of the wood unmarred.

FREE!
Fastener Handbook



Send for your free copy of Handbook No. 7. Complete data for designers on these and many other specialty fasteners. 52 pp., two colors.

Write on your letterhead to Southco Division, South Chester Corporation, 237 Industrial Highway, Lester, Pennsylvania.



SOUTHCO FASTENERS

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Circle 423 on page 19

Circle 424 on page 19→

Drafting Department Heads!

Faced by growing demands of the production boom... the shortage of experienced personnel?

Look how Bruning can help you add

to your Drafting Room!

Look How Many Ways New, Modern Bruning Products Add Manpower to Your Drafting Room by Saving Man Hours of Work!

SAVE
DRAFTING
MAN HOURS

SAVE
REPRODUCTION
MAN HOURS

SAVE
FILING
MAN HOURS

Right now when you need it... add manpower to your drafting room by replacing old or inadequate equipment and materials with these modern, time-saving Bruning Products!

At the *drawing board*, at the *reproduction machine*, at the *files* . . . you can add manpower right now by helping your personnel turn out more work, faster and easier, with these modern, higher-production Bruning products.

See how modern Bruning drafters speed drafting up to 40% on most jobs . . . new and better tracing papers and cloths enable faster drawing and reproduction . . . improved intermediates slash re-drafting time for design changes . . . new, improved Copyflex machines provide faster and more convenient reproduction.

In the face of growing demands of the production boom and the shortage of experienced personnel, you couldn't choose a better time to replace old or inadequate equipment with these new, higher-production products you've been wanting. You couldn't pick a more opportune time to get management approval for new equipment expenditures.

Bruning's wide selection of drafting aids includes not only standard items, but many special time-and-work savers such as dotting pens, proportional dividers, planimeters, special purpose templates, and Bruning electric erasing machines that save hours of finger-cramping manual erasing.

MODERN DRAFTING TOOLS AND SUPPLIES HELP SPEED DRAFTING

MODERN BRUNING DRAFTERS SPEED DRAFTING UP TO 40%

Over conventional equipment, Bruning drafters speed drafting up to 40% on most jobs . . . up to 50% on some structural drawings. Patented "Equipoise" gravity compensator, exclusive touch control indexing provide unrivalled simplicity, precision, and ease of operation. Counterbalanced and Track Drafters slash man hours of work on large drawings. Standard or Civil Engineer protractor heads.

MODERN BRUNING TRACING MEDIUMS SPEED DRAWING AND REPRODUCTION

These new, improved drawing mediums are unsurpassed for translucency, pencil-and-ink taking qualities, workability, permanence. You'll draw easier and faster; get cleaner, sharper prints, in record time.

Just Out! New "Visi-Vel" resin-transparentized tracing paper offers up to 25% faster reproduction speed!

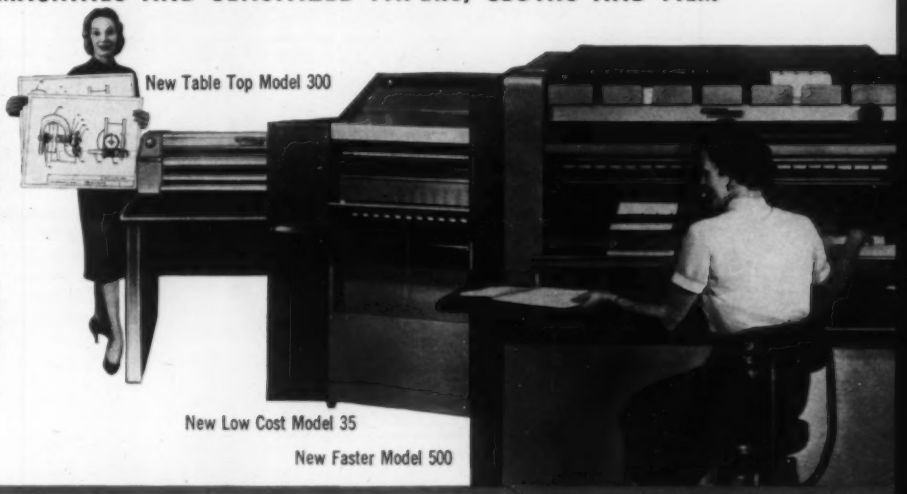
MODERN HAMILTON DRAFTING TABLES REDUCE WASTE MOTION AND FATIGUE

Unique design of Hamilton Auto-Shift lets draftsman work on any part of the board, reach reference table and drawers without leaving his seat. And you can put six Auto-Shift tables where you now have four boards with separate reference desks.

MODERN COPYFLEX MACHINES AND SENSITIZED PAPERS, CLOTHS AND FILM

Speed Reproduction! New, advanced Copyflex models bring you faster reproduction speed and a host of operator conveniences such as fast return of originals, automatic separation, front or rear delivery. And all the benefits of diazo black-on-white reproduction, plus problem-free operation and installation. No fumes, no exhaust ducts. There's a Copyflex model to meet every need and budget. New, better Copyflex sensitized materials work together with Copyflex machines to speed reproduction, give you premium results.

Slash Re-Drafting Time! Save up to 90% tracing time by making modern Copyflex intermediates (translucent prints) of drawings to be re-worked. Mask out unwanted portions before reproducing the intermediate, add new lines or sharpen up weak lines on the intermediate itself, produce sharp, clear prints from the intermediate.



New Table Top Model 300

New Low Cost Model 35

New Faster Model 500

HAMILTON WOOD FILING UNITS

Combine exactly the interchangeable units you need—in higher stacks—to save time and space. Sturdy oak construction.

PLAN HOLD FILING EQUIPMENT

Save time, space, and damage in filing large active plans. Spring-loaded, clamp-style binders eliminate punching, stapling, bolting or folding of plans. Binders are easily mounted in wall racks, floor stands, cabinets. A binder holds up to 150 plans.

MODERN HAMILTON ALL-STEEL UNITSYSTEM FILES SAVE TIME, SPACE; PERMIT ORDERLY EXPANSION

You file drawings and records in units especially designed for them by size and frequency of use. Drawings are easier to file and find, which saves time. UnitSystem's interlocking feature lets you combine exactly the units you need—in higher stacks—which saves space. It lets you expand your filing set-up gradually, efficiently, and economically.

GIVES YOU MORE TO HELP SAVE MAN HOURS . . . ADD MANPOWER TO YOUR DRAFTING ROOM . . .

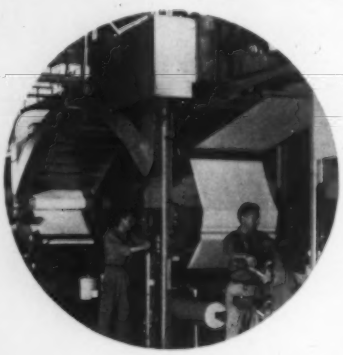
3 more reasons why you can depend on Bruning to help you

Save Man Hours...Add Manpower to Your Drafting Room!

Researcher, manufacturer, and supplier . . . Bruning saves you many man hours by providing a single, convenient, dependable source for everything you need in top-quality drafting room supplies and service. You simplify ordering and stocking, save time and money. You get the following important benefits!

New and Better Products— from Bruning Research and Engineering

Bruning Research and Engineering has introduced such great time-and-work savers as the first pencil tracing cloths, the first fume-free whiteprinters in America, the first band-type drafting machines. Today, by virtue of its modern laboratories and large engineering staffs, Bruning still leads the way. In just the last two years, Bruning has introduced five new, advanced reproduction machines, many newly improved tracing materials. You can count on more new and better products coming to help you save man hours, add manpower.



Consistently High Quality —from Bruning Manufacturing

In its own modern paper converting plants at Teterboro, N.J., Chicago, Kansas City, Los Angeles, and Toronto, Ontario, Bruning controls quality all the way to bring you tracing mediums and sensitized materials of dependable, consistent high quality. The famous Copyflex reproduction machines are entirely Bruning manufactured to provide you the finest in reproduction performance. You get better results, minimize the risk of trouble and loss of man hours.

▲ 36 Bruning Sales-Service Branches
● 6 Bruning Distributors
◬ 5 Strategically Located Plants

The Product and Help You Need When You Need Them—from Bruning Sales Service

You suffer no costly delays—no loss of man hours—for lack of supply or service. With the most comprehensive network of sales-service branches, distributors, and plants in its field, Bruning assures you of prompt, dependable service and supply.

Your nearby Bruning branch is headquarters for a capable staff of Bruning sales-service specialists who are immediately available to you. Your nearby Bruning branch or distributor carries a full line of Bruning products and is staffed and equipped to give you fast, efficient supply.

Right now is the time to capitalize on Bruning's great time-and-work saving products and Bruning's outstanding service and supply. They work together to help you save man hours—add manpower to your drafting room, now when you need it!

BRUNING

America's Leading Supplier of Engineering and Drafting Equipment

CHARLES BRUNING COMPANY, INC., 4700 MONTROSE AVE., CHICAGO 41, ILLINOIS

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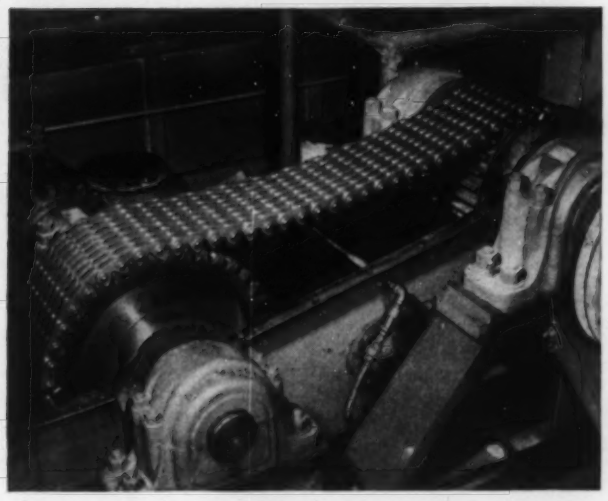
A-2320

Printed in U.S.A.

Why the design engineer is ahead when specifying LINK-BELT Silent Chain

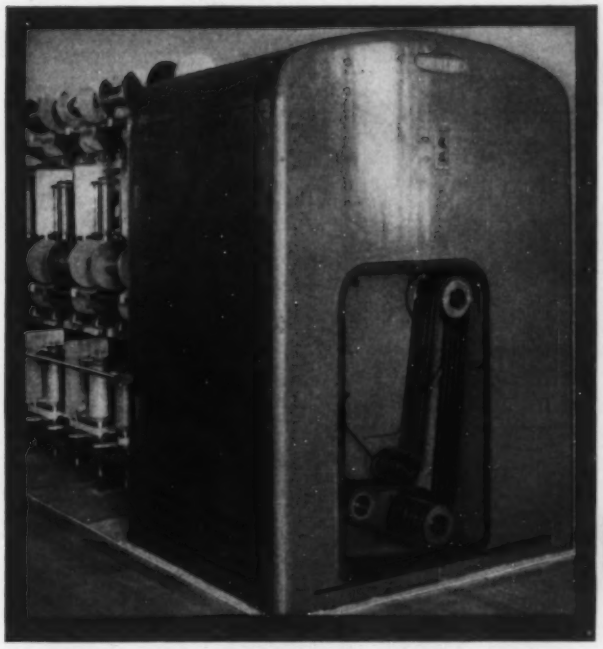


Silent chain driving from a 200-hp, 1200-rpm motor handles comfortably the extreme peak loads of draw bench service.

No other drive does so many jobs so well

In applications involving the transmission of fractional or thousands of horsepower, high rotative or linear speeds—no other drive can match the effectiveness of Link-Belt silent chain.

You are assured of better than 98% sustained efficiency throughout its long life. It is often lower in first cost and always lower in ultimate cost—frequently runs for 20 to 30 years with only routine attention. Get the full story on Link-Belt silent chain. Write for Book 2425, or call your nearby Link-Belt office.



Uptwister uses duplex silent chain. Note the simplicity of this drive operating multiple shafts in a textile mill.

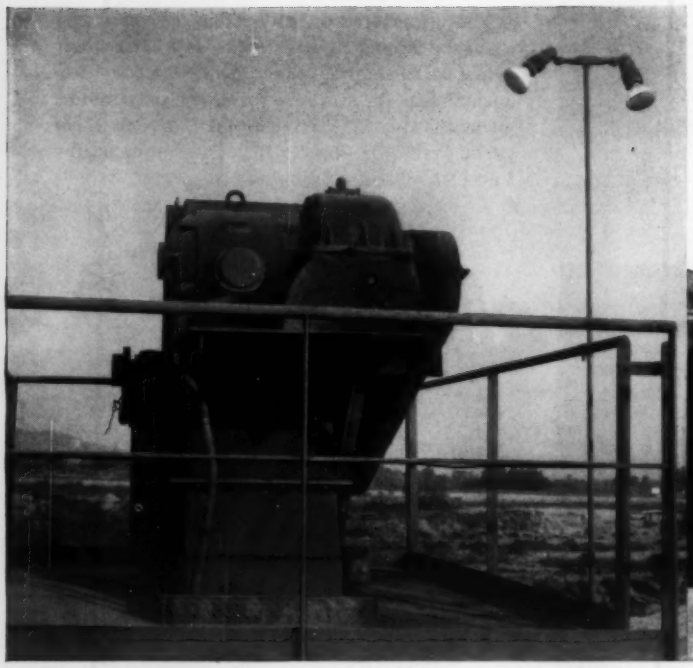
LINK-BELT

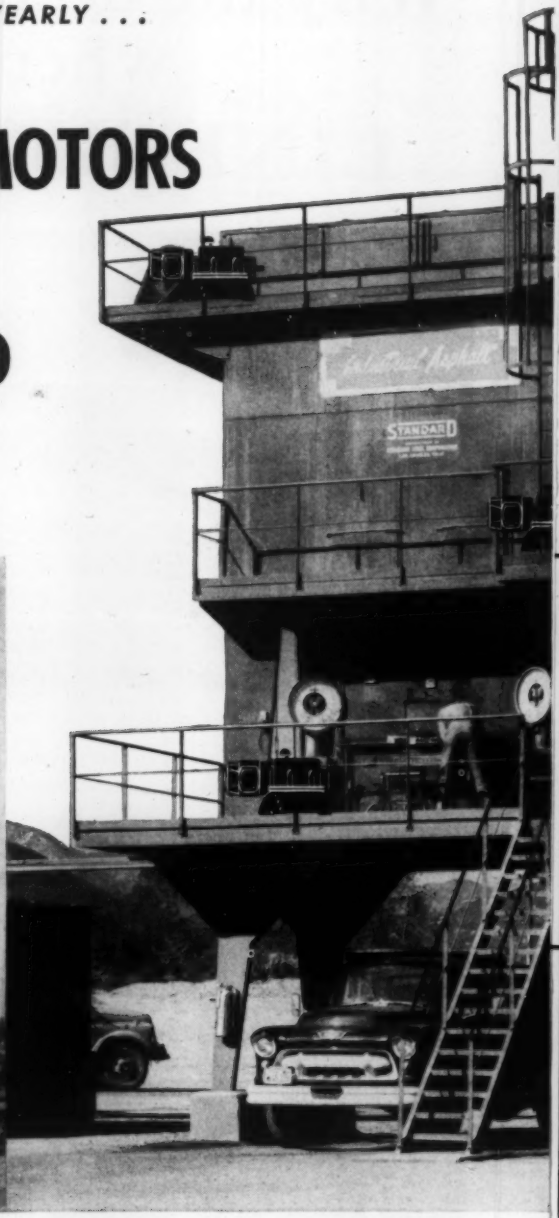
CHAINS AND SPROCKETS

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office: New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 13,938

MIXING NEARLY 2 MILLION TONS OF ASPHALT YEARLY . . .

WESTINGHOUSE GEARMOTORS SET 15-YEAR DEPENDABILITY RECORD

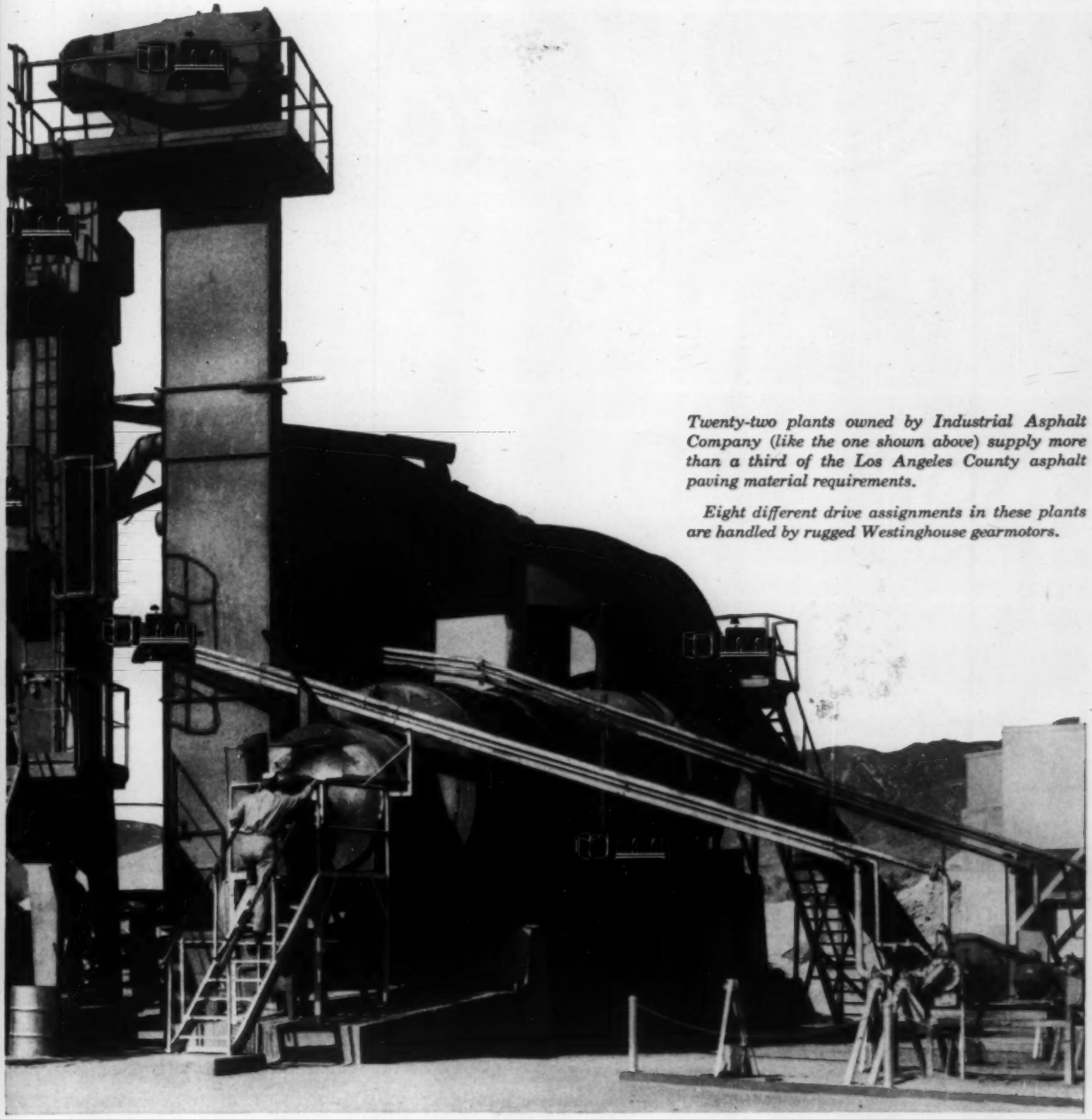




Mounted on top of a 36-foot high aggregate elevator, this Westinghouse gearmotor moves 6600 lbs. of rock a minute from the ground to the vibrating screen. There has not been one failure in 15 years in either motor or gearing despite repeated high torque requirements and adverse weather conditions.

"We have used Westinghouse gearmotors in our plants for more than 15 years," reports E. J. Woodward, Chief Engineer of Industrial Asphalt, Los Angeles. "Gearmotors driving the hot elevators take the toughest strain. Most of these units have been operating 15 years without replacement or addition of new bearings or motor armature. These drives take occasional overloads safely, too. For example, we've increased output from 230 to 283 tons per hour without a failure."

"As a manufacturer of these asphalt plants, we demand absolute dependability in all components,"



Twenty-two plants owned by Industrial Asphalt Company (like the one shown above) supply more than a third of the Los Angeles County asphalt paving material requirements.

Eight different drive assignments in these plants are handled by rugged Westinghouse gearmotors.

remarked M. B. Preeman, of Standard Steel Corporation. "Dependable service is the primary reason for using Westinghouse gearmotors in Standard Steel asphalt plants."

Here's another example of the type of service you can expect from Westinghouse gearmotors and speed reducers. You can get immediate delivery in horsepower ratings from 1 to 100; reduction ratios to 58.3:1. Call your local Westinghouse sales engineer, or write, Westinghouse Electric Corporation, Gearing Division, 200 McCandless Avenue, Pittsburgh, Pennsylvania. J-07355

YOU CAN BE SURE...IF IT'S

Westinghouse

from one hour to one minute...

HELIARC Cutting Whizzes Through Aluminum

One of the first aluminum fabricators to use LINDE's new HELIARC cutting process reveals savings of more than 95 per cent over conventional chipping methods—jobs normally requiring 1 and 5 hours to complete are whisked through in only 1 and 4½ minutes respectively. Graver Tank and Manufacturing Company reports beveling, grooving, shaping, and cutting are all performed on ⅝-in. thick, 52S aluminum plate at substantial time, space, and cost savings.

Incredible, but true: HELIARC cutting can attain speeds as high as 600 inches per minute, and cut aluminum in thicknesses up to 1½ inches. No special skill is required. A certified welder can do excellent cutting jobs after less than one hour of instruction.

Get the full story on revolutionary new HELIARC cutting. Call your LINDE representative, or write for free illustrated literature, Form 50,095.

Linde Air Products Company

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DU PONT

PRODUCT ENGINEERING NEWS

LATEST PROPERTY AND APPLICATION DATA ON THESE VERSATILE ENGINEERING MATERIALS: ZYTEL®, TEFLON®, LUCITE®

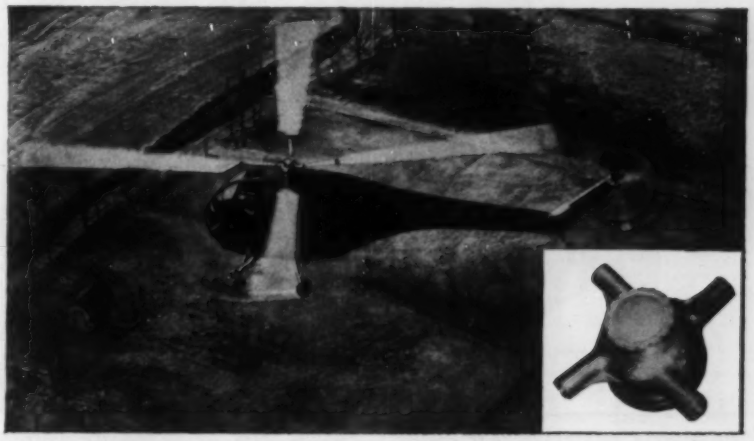
Tough, wear-resistant bearings of ZYTEL® nylon resin outperform conventional materials in helicopter rotor

"This application has solved all spar-tube galling problems," reports the Rotor Group Engineer at Doman Helicopters, Inc. "By eliminating galling problems in the Doman Rotor, there is no longer a need for field maintenance of the blade-retention system."

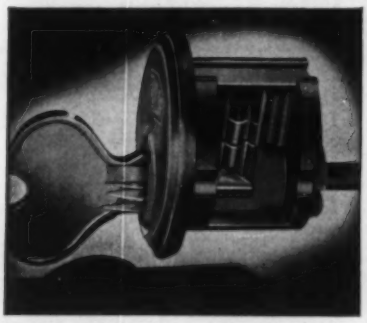
The application: a liner of ZYTEL nylon resin in the main rotor-blade bearing packs which support spar tubes in the arm of the rotor hub. The use of ZYTEL solved a problem of fretting corrosion which destroyed other sleeve bearings.

The excellent bearing characteristics and toughness of ZYTEL solved this engineering design problem. Other desirable mechanical properties include ease of fabrication by molding or machining from stock, strength in thin sections and resistance to impact.

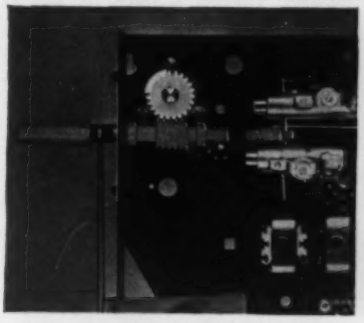
Many uses of ZYTEL are based also on its good electrical insulating properties. ZYTEL nylon resin is rated for intermittent operation up to 250°F.; for continuous operation at such elevated temperatures, heat-stabilized grades are available. ZYTEL resists the action of many common chemicals. Because of the low-friction characteristics and resiliency of ZYTEL nylon resin, gears, cams and bearings operate quietly, with little or no lubrication. Complicated shapes can be molded to precise dimensions around inserts.



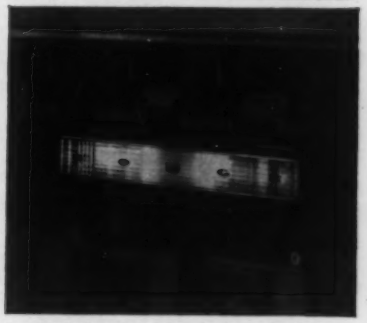
SLEEVE BEARING of ZYTEL supports spar tube in the arm of helicopter rotor hub. Bearing is 2" in diameter, 6" in length. Toughness of ZYTEL enables it to outperform other bearings. Spar-tube life is extended, maintenance reduced. (Made by Doman Helicopters, Inc., Danbury, Connecticut.)



CYLINDER PLUG for door lock is molded of Du Pont ZYTEL nylon resin. Cylinder lubrication is not necessary because of the low coefficient of friction of ZYTEL. The cylinder plug does not stick and turns smoothly in the lock. Unlike certain metals, the cylinder plug is corrosion-resistant and weatherproof and is not subject to electrolytic action. The hardness, durability and the abrasion resistance of ZYTEL nylon resin help insure against wear, and provide long service life for all parts molded of ZYTEL. (Door lock manufactured by The Taylor Lock Company, Philadelphia, Pennsylvania.)



INTRICATE TUNING SHAFT for radio selector mechanism is precision-molded of ZYTEL nylon resin. The shaft needs no lubrication yet operates easily. It is non-magnetic and has high electrical resistance. Stiffness and torsional strength are more than adequate. Shaft has integrally molded gears, washers, holes, bevel and step. Considerable savings in fabrication costs over metal were realized. Components of ZYTEL nylon resin usually need no further finishing after molding. (Molded by Engineered Nylon Products, South Bend, Indiana, for Granco Products, Long Island City, New York.)



ILLUMINATOR LENS made of Du Pont LUCITE® acrylic resin distributes soft, even light throughout the interior of the new Norge Home Freezer. Located in the door, the lens also serves as an attractive name plate. Du Pont LUCITE is strong and tough . . . has remarkable optical properties, transmitting 92% of impinging light. LUCITE has high resistance to shattering . . . good dimensional stability. (Lens molded by Stimsonite, Division of Elastic Stop Nut Corporation of America, Chicago, Illinois; Freezer by Norge Sales Corporation, Chicago, Illinois.)

OVER

Circle 428 on page 19

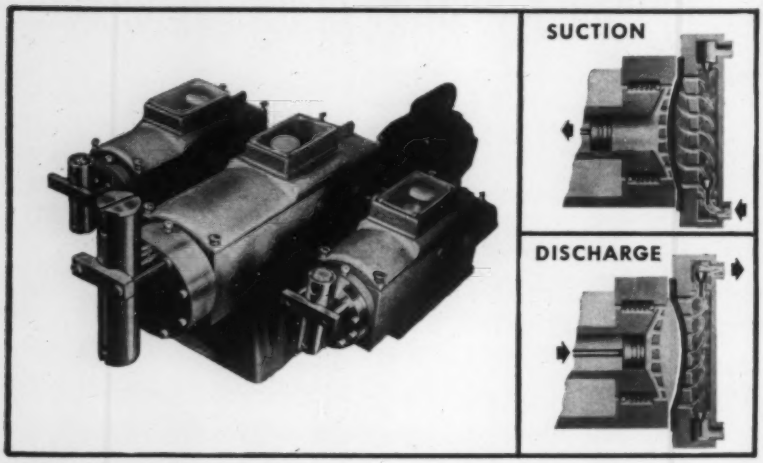
DU PONT

Better Things for Better Living ... through Chemistry

PRODUCT ENGINEERING NEWS

LATEST PROPERTY AND APPLICATION DATA ON THESE VERSATILE ENGINEERING MATERIALS: ZYTEL®, TEFLON®, LUCITE®

Chemical inertness, high flex strength of TEFLON® resins are featured in pumps handling powerful corrosives



"PULSAFEEDER" DIAPHRAGM PUMP employs a tough, flexible diaphragm of a chemically inert TEFLON tetrafluoroethylene resin. Model shown is a triplex assembly used in handling hydrogen peroxide, sodium hydroxide and sodium silicate for bleaching fabrics. (Flexible diaphragm of TEFLON trademarked Fluorlastic by the Joclin Manufacturing Company, Wallingford, Connecticut; pump by Lapp Process Equipment Division of the Lapp Insulator Company, Inc., Leroy 6, New York.)

The Lapp "Pulsafeeder" can be used as a metering pump or as a proportioner, pumping two or more liquids in an established ratio. In the case of highly corrosive fluids, it depends on tough, flexible diaphragms of a TEFLON tetrafluoroethylene resin for resistance to chemical attack plus high strength.

On the piston side of the diaphragm, TEFLON tetrafluoroethylene resins are unaffected by any type of oil used as the hydraulic activating medium. On the pumpage side, TEFLON resins are completely inert to acids, aliphatics, aromatics, chlorinated hydrocarbons, alkalies and, in fact, almost any chemical or solvent in commercial use. The few exceptions to this include attack by the alkali metals under certain conditions. At high temperatures and pressures, halogens and certain halogenated chemicals and solvents may also affect TEFLON. TEFLON is rated for use to 500°F. and does not become brittle even at temperatures near absolute zero.

TEFLON 1, TEFLON 5 and TEFLON 6 resins may be used to make durable components such as seals, gaskets, packings and bearings. They are superb dielectrics.

The properties of TEFLON resins may have application in one of your own designs. Mail the coupon for a full report on uses and characteristics.

E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Dept.
Room 14530, Du Pont Building, Wilmington 98, Delaware

Please send me more information on the Du Pont engineering materials checked: ☐ *ZYTEL;* ☐ *TEFLON;* ☐ *LUCITE. I am interested in evaluating these materials for:*

_____

Name_____

Company_____ Position_____

Street_____

City_____ State_____

Type of Business_____

IN CANADA: Du Pont Company of Canada (1956) Limited, P. O. Box 660, Montreal, Quebec.

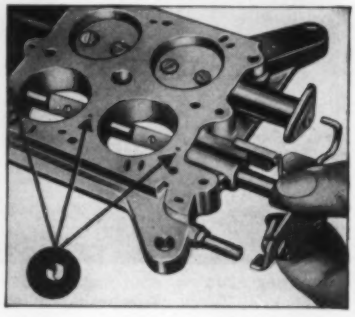
Thin-walled tubing of TEFLON® resins withstand soldering temperature, simplify assembly

TEFLON tetrafluoroethylene resins maintain high dielectric strength at elevated temperatures. They also have high surface resistivity, dropping only to 10^{13} ohms at 100% relative humidity. TEFLON maintains full electrical insulating characteristics, even when flexed or bent during assembly and installation. This combination makes it possible to miniaturize an electrical assembly without fear of dielectric failure.

For example, thin-wall tubing of a TEFLON resin simplifies assembly of component parts in a series of miniature rotary tap switches. Since TEFLON resins will not burn, melt or decompose when connections next to them are soldered, assembly of switch parts is easier, faster, and the possibility of accidental grounding is minimized. The thermal stability of TEFLON resins, even in thin sections, is demonstrated in this tubing where the wall thickness is only .014". The nominal inside diameter is .075". TEFLON resins meet Class H, AIEE standards for maximum insulating temperatures.

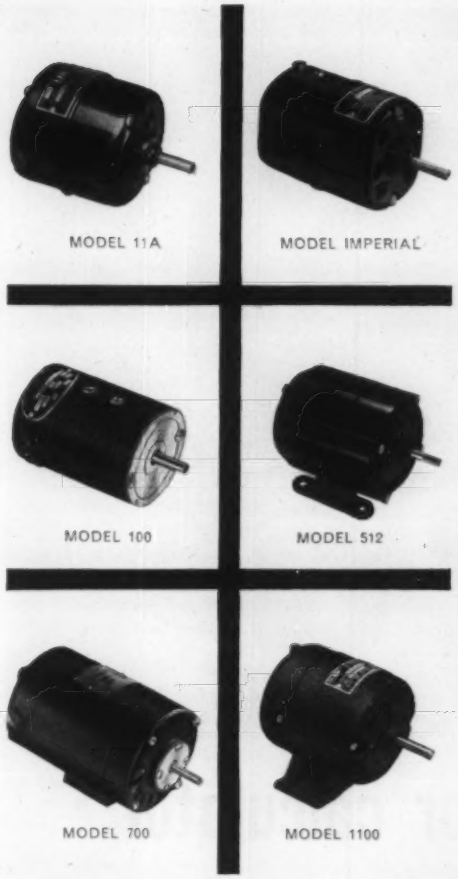
TEFLON resins are non-flammable, have good mechanical strength and are completely unaffected by sunlight or outdoor weathering. They have zero water absorption by ASTM test D570-42, resist corrosion and growth of fungus, are chemically inert.

Carburetor bearing problem solved with TEFLON® resins



Carburetor bearings of a TEFLON resin are used on the secondary throttle shaft of carburetors in all 1957 models of two popular cars. "Self-lubricating" property of TEFLON eliminated a serious problem of slip-stick action of the shaft caused by gums in gasoline. The use of carburetor bearings of TEFLON eliminated the necessity for chrome-plating the shafts. Top product performance is assured, at decreased manufacturing costs. (Carburetor by Holley Carburetor Company, Van Dyke, Michigan; bearings by Modern Industrial Plastics, Inc., Dayton, Ohio.)

Circle 428 on page 19



MORE THAN 50,000 DIFFERENT SPECS HAVE BEEN FILLED BY THESE 6 HOWARD UNIVERSAL AND D.C. FRACTIONAL H.P. MOTORS

These 6 Howard motors account for over 50,000 specifications, both military and commercial. One reason for this wide use is Howard's ability to produce variations *exactly* suited to specific needs.

Howard motors have such field-proven engineering features as automatic slot cell insertion, which practically eliminates "grounds;" Zanderoll processed double dipped and double baked armatures providing deep, uniform varnish penetration for high bond strength and rock-hard coils minimizing "shorts and opens;" improved brushholder construction for accurate alignment and longer life; 2-stage, 3-plane dynamic balancing; and automatic winding for tough compact coils, giving uniform performance.

If you are currently using universal and D.C. motors from 1/200th to ½ H.P., check with Howard today.

GEAR REDUCTION UNITS

Model	Ratio min.	Ratio max.
11A	3:1	2700:1
Imperial	3:1	2700:1
100	3:1	2700:1
512	3:1	2700:1
700	21.5:1	2600:1
1100	3:1	2700:1

ELECTRICAL SPECIFICATIONS

MODEL 11A		MODEL 100		MODEL 512	
SERIES MOTOR	SHUNT MOTOR	SERIES MOTOR	SHUNT MOTOR	SERIES MOTOR	SHUNT MOTOR
15M	3.5-10M			15M	2-9M
5-10M	3-8M	5-10M	1.8-6M	5-10M	1.8-6M
1/75 No Fan	1/75 No Fan	1/50	1/50	1/10	1/12
1/20	1/20	1/13	1/13	1/5	1/6
.4	.4	.35	1.6 at 24V	1.5	1.5
.75	.75	1.0	5 at 24V	3.0	3.0
30	30	35	35	50	45
35	35	45	45	60	55
12-115	6-120	12-120	6-32	24-230	12-230
CW, CCW, REV.	CW, CCW, REV.	CW, CCW, REV.	CW, CCW, REV.	CW, CCW, REV.	CW, CCW, REV.

Maximum H.P. ratings are shown. Variations are available for less power to meet application requirements.

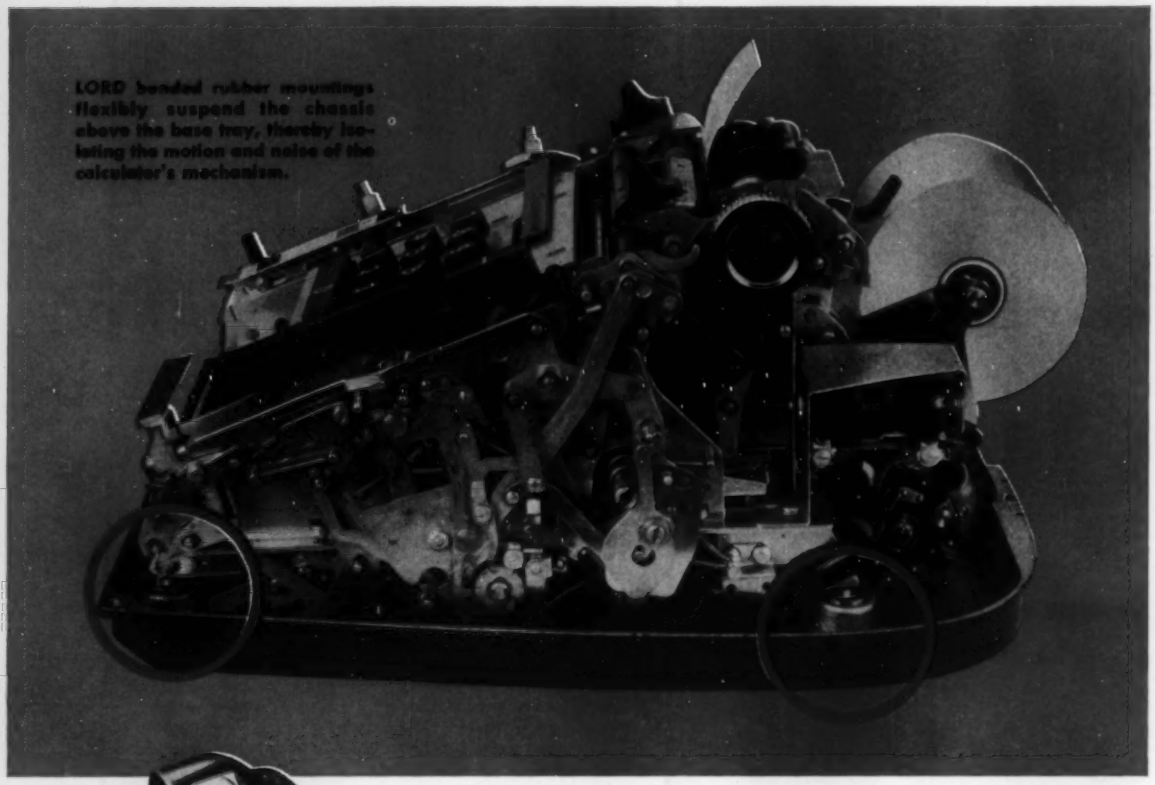
Other Howard motors: UNIVERSAL & D.C. 1/200 to 1/2 h.p. • SHADED POLE 1/2000 to 1/8 h.p. INDUCTION 1/1400 to 1/8 h.p. • SERVO MOTORS • GEAR MOTORS • BLOWERS

HOWARD INDUSTRIES, INC., 1735 STATE ST., RACINE, WIS., TELETYPE: RAC 344

Sales Offices 208 S. La Salle St., Chicago 4 / 942 S. La Brea Ave., Los Angeles 36 / Room 4822, Empire State Bldg., New York 1 / 300 Broadway, Camden, New Jersey

Buy Defense Bonds

DIVISIONS: EMC ELECTRIC MOTOR CORPORATION · CYCLOHM MOTOR CORPORATION · RACINE ELECTRIC PRODUCTS


LORD bonded rubber mountings flexibly suspend the chassis above the base tray, thereby isolating the motion and noise of the calculator's mechanism.

... new Victor calculator supported by LORD bonded rubber mountings

LORD tube form mounting used in Victor Calculator has rubber element permanently bonded to inner and outer metal members.

Four LORD bonded rubber mountings concealed beneath the modern styling of this compact, rugged Victor Calculator provide operating quietness by controlling noise-creating vibrations.

Isolating the vibrating machine from the "sounding board" cabinet and desk top, these mountings efficiently control vibration and sound transmission to produce a hushed office atmosphere.

The bonded rubber mountings, specially designed for Victor by LORD engineers, had to be resilient enough to absorb the oscillation of the mechanism yet provide a firm support. This is another example of LORD's success in diversified applications of their engineered vibration control systems.

Whatever your vibration problem, call or write your nearest Field Engineer or the Home Office, Erie, Pa.

ATLANTA, GEORGIA · CEdar 7-1123
BOSTON, MASS. · HAncock 6-9135
CHICAGO, ILL. · Michigan 2-6010
CLEVELAND, OHIO · SHadyside 9-3175
DALLAS, TEXAS · Riverside 1-3392
DAYTON, OHIO · Michigan 8871
DETROIT, MICH. · TRinity 4-2060
LOS ANGELES, CAL. · HOllywood 4-7593
NEW YORK, N. Y. · Circle 7-3326
PHILADELPHIA, PA. · LOcust 4-0147

"In Canada—Railway & Power Engineering Corporation Limited"

LORD MANUFACTURING COMPANY · ERIE, PA.

LORD BONDED RUBBER

designers and producers of bonded rubber products since 1924

Circle 430 on page 19

Circle 431 on page 19→

the only complete line of reduced voltage STARTERS

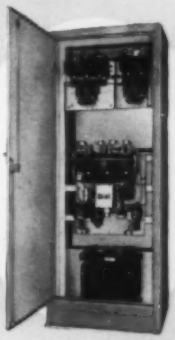
For SATISFYING Power Company and Application Requirements . . .

BULLETIN 646
manual autotransformer TYPE

A strictly "modern" starter. Silver alloy, *air break* contacts provide long, trouble free life . . . without the messiness and maintenance of oil-immersed contacts. Operation is simple . . . a bell signals proper interval—which can be adjusted—for switchover from START to RUN. Air break contacts standard in ratings to 75 hp, 220 v; 150 hp, 440-550 v. Also furnished oil-immersed up to 125 hp, 220 v; 250 hp, 440-550 v.

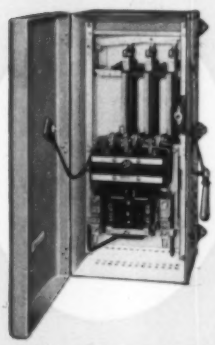
BULLETIN 746
automatic autotransformer TYPE

Employs autotransformer connected in delta to reduce line voltage for starting squirrel cage motors that should not be started on full line voltage. Automatically operated by solenoid contactors with double break, silver alloy contacts. Adjustable timing relay controls accelerating period. Taps are provided on the autotransformer to adjust the motor starting voltage. Ratings up to 300 hp, 220 v; 600 hp, 440-550 v.



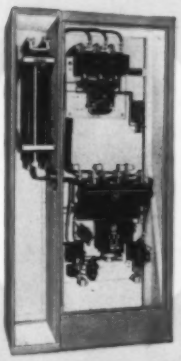
For Velvet S-M-O-O-T-H STARTING . . . nothing equal on the market!

BULLETIN 640
manual stepless resistance TYPE



Graphite compression disc resistors provide smooth, stepless starting of polyphase squirrel cage motors. Operated by hand lever, the smooth starting of the motor is under the control of the operator. Limits starting current and prevents lamp flicker. Accurate overload relays protect motors against burnout. No-voltage protection provided. Ratings to 200 hp, 220-440-550 v.

BULLETIN 740
automatic stepless resistance TYPE



Preset and adjustable graphite disc resistors are automatically inserted in series with squirrel cage motor at starting. Adjustable timing relay operates contactor, which automatically cuts out resistors after predetermined starting period. Resistors can be adjusted to motor and load conditions for velvet smooth acceleration. Accurate thermal relays protect motors. Ratings to 200 hp, 220-440-550 v.

8-57-MR

A-B Quality

Write for Bulletin

Allen-Bradley Co.
1316 S. Second St.
Milwaukee 4, Wis.

In Canada—
Allen-Bradley
Canada Ltd.
Galt, Ont.

ALLEN-BRADLEY
MOTOR CONTROL
QUALITY

see next page

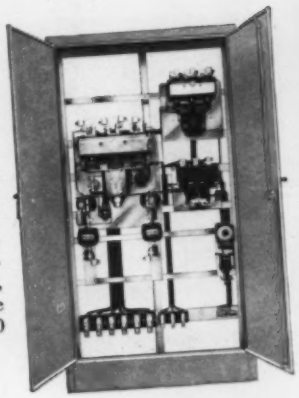
...and still other

ALLEN-BRADLEY

reduced voltage STARTERS

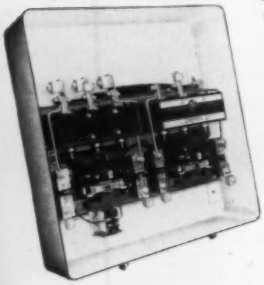
BULLETIN 741...AUTOMATIC multipoint resistance TYPE

An automatic starter that will satisfy power company requirements for starting of motors on network systems. Resistances are automatically inserted in the line at starting, and are short circuited in steps at definite time intervals. Time intervals can be adjusted from 1 to 5 seconds for ideal starting under various load conditions. Available in 2, 3, and 4-point starters. Made in ratings up to 300 hp, 220 v; 600 hp, 440-550 v.



BULLETIN 736...AUTOMATIC part winding TYPE

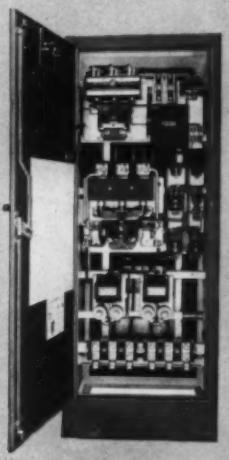
For use with squirrel cage motors having two separate parallel stator windings. Provides economical reduced voltage starting when starting current does not exceed power company limitations. Two types—Style A is a 2-step starter available in ratings up to 200 hp, 220 v; 400 hp, 440-550 v. Style B is a 3-step starter with resistance in series with the motor on the first step. In ratings up to 200 hp, 220-440-550 v.



A-B Quality

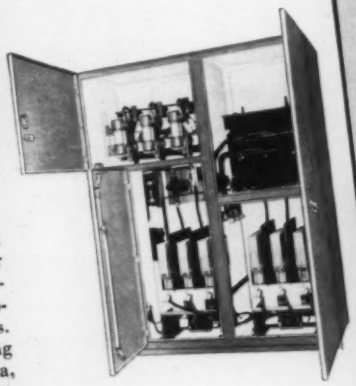
BULLETIN 742...AUTOMATIC stepless, graphite resistance TYPE

This is the ultimate in smooth acceleration of squirrel cage motors. The graphite disc resistors vary in resistance smoothly and steplessly as the pressure on them is automatically changed. Also, the rate at which pressure is applied can be varied over a wide range. Lamp flicker on network systems used for both power and light is completely eliminated. Also ideal where a starting shock to driven machines may cause serious trouble or affect machine life. Ratings to 200 hp, 220-440-550 v.



BULLETIN 1172...AUTOMATIC high voltage, air break reactor TYPE

For starting high voltage squirrel cage motors at reduced voltage. Simple solenoid air break contactor has only *one* moving part, and the double break, silver alloy contacts need no maintenance. These contactors are designed for heavy duty industrial service and can be used for inching or jogging. Reliable overload relays protect the motor at all times. Starters have interrupting capacities of 150,000 kva, 2300 v; 250,000 kva, 4600 v. Made in ratings up to 1500 hp, 2300 v; 2500 hp, 4600 v.



ALLEN-BRADLEY

QUALITY

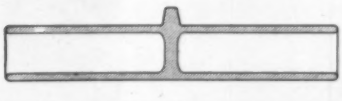
MOTOR CONTROL

Allen-Bradley Co.
1316 S. Second St., Milwaukee 4, Wis.
In Canada—Allen-Bradley Canada Ltd., Galt, Ont.

8-57-AB

THE CAMERON CURE FOR DESIGN DILEMMA

How would you produce this relatively simple component? Actually, it's not simple but Cameron had the cure. This actuator for the horizontal stabilizer of the North American F-100 fighter plane is a cylinder with a thin solid center section and one central protrusion. For-



merly it was a weldment – two sections of tube stock with a small forging in the center – right here is where the headache developed because a cold bending operation was required. Welds parted, rejects were too high. The Cameron split-die forging process changed all of this.

Now it is forged in one piece. Grain structure is excellent, final machining and cold bending are easy—rejects are low and design department spirits are up.

If you have a problem in a ferrous component (200 to 5000 lbs.), especially one for critical service, with internal curvatures and perhaps odd protrusions which cannot be forged in conventional dies, CALL ON CAMERON.

Our facilities are complete from melting of high quality alloy steels for our unique forging operations to final machining if desired. Many knotty design problems are finding a simple solution in the unusual shapes and quality controlled alloys coming from Cameron. Write or call...

IRON WORKS, Inc.
SPECIAL PRODUCTS DEPARTMENT
P. O. Box 1212 Houston, Texas

Circle 432 on page 19

there are three important elements in this scene at AMWELD®

PRECISION PRODUCTS—American Welding specializes in the forming, flash welding, sizing and machining of rings and circular components, from 6" to 96" in diameter, of ferrous and non-ferrous metals, including titanium and heat-resisting alloys.

QUALITY CONTROL—Amweld works to rigid specifications. We are proud that we are suppliers of rings and components to every major U. S. jet engine manufacturer.

TRAINED PERSONNEL—Amweld has over 1,100 employees who are skilled in the field of welding and forming rings and components. Amweld offers research and engineering services to insure finest quality at the fairest prices. Why not contact the Industrial Products Division of

THE AMERICAN WELDING & MANUFACTURING CO. 130 Dietz Road • Warren, Ohio

AMERICAN WELDING

The World's Leading Manufacturer of Welded Rings

(Advertisement)

New stop clock designed for accuracy, versatility

Today's product designer, control systems engineer, nuclear physicist, and graphic panel manufacturer have a common need—an instrument capable of measuring elapsed time to a hundredth of a second, with an accuracy better than 0.02 of 1%.

Wide field—wide requirements

But there the sameness ends—the nuclear physicist needs a hermetically sealed device for remote control; the product designer requires load switches and local pushbutton reset; the graphic panel man wants smart appearance. The lab technician wants a portable model. The military asks for the smallest unit consistent with reliable readings, while the sports event timekeeper must have a large dial.

How can you meet these diverse requirements? Well, here's the answer to that question—a product of Cramer's experience and knowledge of precision timing.

Accuracy for everybody

You select a small, powerful and inherently accurate drive motor, add a 110-tooth positive clutch and apply it on the high-speed shaft. Back it up with a potent relay. When the signal comes, the unit responds instantly, and we have *accuracy*.

All-electric operation for flexibility

Add heart cams on the mainshaft and a rugged solenoid to belt them home within 1/10 second after the reset switch is operated. Now we have *electrical reset*, either remote or local.

For *versatility*, provide for load switches with cams on fast or slow pointer shafts. Cut and set at the factory, cams will offer a variable number (and duration) of pulses per second or minute, or with load switches wired in series, the unit can be used as a highly precise time delay relay or interval timer.

Commercial or Mil-Spec housings

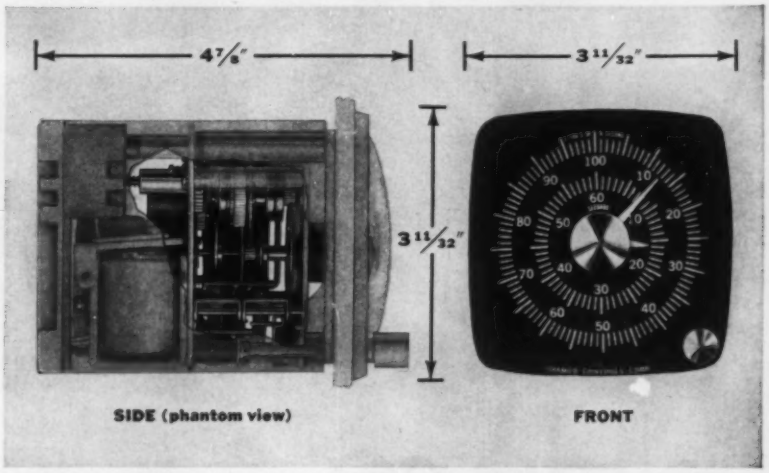
Now let's enclose the mechanism. Commercial housing is dust-tight and has a 12-place terminal block. Also developed: a militarized model to withstand high vibration, shock and severe environments. A deep-drawn solder-sealed enclosure with 14-pin glass-beaded header, evacuated and hermetically sealed will do it.

Dials, pointers—Loewy styled

What's left? The business end of things—dial and pointers. Let's tackle this for readability, and at the same time, shoot for eye-appeal. This time we'll go to the *styling* experts — famous industrial designers, Raymond Loewy Associates. They come up with the last word in human-engineered dial-pointer combination for fast, exact readings. Frame it with a pleasing bezel that can be finished to match or harmonize with your panels.

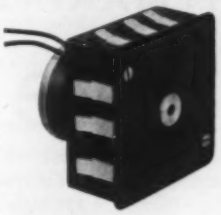
Now it looks like the precise instrument that it is—the new Cramer Type 691 Time Totalizer. Bulletin PB-691 tells more about it. Write for your copy today. The Cramer Controls Corp., Box 6, Centerbrook, Conn.

P.S. We've got the six-inch dial version and the portable model, too. 7.20

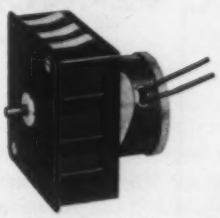


NEW time totalizer. Type 691 features instantaneous electrical reset, accuracy within 0.02 of 1%. Standard ranges: 60 seconds in 1/100 sec., 60 minutes in 1/100 min., and 60 minutes in seconds. Factory-set cam-operated load switches (rated at 5A, 250 vac, resistive) can be supplied. Available for standard voltages at 50, 60 cps; for 400 cps with d-c clutch; and for d-c voltages. Mechanical and electrical life in excess of 1-million operations.

TWO MORE NEW CRAMER PRODUCTS



NEW cycling timer. Type 571, ideal for "cycling" electrical equipment such as appliances, vending machines, advertising displays, at lowest possible cost. 1 to 4 poles. Speeds from 1 rpm to 1 revolution in 8 days with 30-amp contacts. Faster speeds with lighter contacts on special order.



NEW interval timer. Type 271, for built-in applications. Provides an economical way of timing appliances, photo equipment, ovens, etc., for manually preset interval. 1 or 2 poles. Time ranges from 45 seconds to 6 days with 30-amp contacts. Normally furnished without knob or dial.

TALK IT OVER WITH

CRAMER CONTROLS CORPORATION

Circle 434 on page 19

Here at last

FULL 42-INCH PRINTMAKING IN A CONVENIENT

Table Model

Now, TABLE MODEL convenience, LOW COST and FULL WIDTH are combined in *one* whiteprinter—the new Ozalid Streamliner 200!

Now, anyone can turn out sparkling whiteprints in seconds—up to 42 inches in width! In the small office, the new Streamliner 200 gives you prints whenever you need them. For the large firm, it handles "rush work"... saves costly interruptions of volume printmaking... *stands by* when other machines are "down" for service.

Compact in design, Streamliner 200 stands just 22″ high . . . 38″ deep, with feedboard. Prints stack automatically. Controls are simple, easy to operate. Stand, shown above, is optional.

Why not test-run your own tracings through the Streamliner 200? Call your local Ozalid representative or write: Ozalid, Department GG-5, Johnson City, New York.

A Division of General Aniline & Film Corporation
In Canada: Hughes Owens Company, Ltd., Montreal

OZALID®

First name in whiteprinting

Circle 435 on page 19

Using

DU PONT ELASTOMERS

NEOPRENE · HYPALON®

4 in Design

Molded spark-plug boots of HYPALON® withstand ozone and heat (270°F.)

Several years ago a leading car manufacturer set out to find a new rubber material for its spark-plug boots. New designs had increased engine horsepower but at the same time reduced engine space, thus increasing the temperature under the hood. Existing boots couldn't take the punishment of temperatures averaging 270°F. with occasional peaks of 340°F., or the increased ozone concentration caused by reduced space under the hood.

After testing several resilient materials, they decided on Du Pont HYPALON synthetic rubber. HYPALON has exceptional resistance to deterioration at high temperatures and it is virtually ozone-proof. The problem was solved. HYPALON has been specified for the spark-plug boots on this manufacturer's new V-8 and six-cylinder engines.

HYPALON also offers outstanding resistance to weather and oxidizing chemicals. And it can be compounded in an unlimited range of sunlight-stable colors.

Why not investigate the possibilities of using HYPALON in your designs? We'll be glad to send you complete property data and application information. If you have a specific problem, please let us know.

HYPALON spark-plug boots resist high ozone concentrations and temperatures averaging 270°F., in the engine of one of today's leading cars.

Circle 436 on page 19

Why Remington uses NEOPRENE on its new model stud driver

Powerful and fast, the new Remington "MIGHTY-MITE" stud driver uses a 22-caliber cartridge to drive ¼" studs in steel or concrete without pre-drilling.

The "MIGHTY-MITE'S" barrel must be twisted and held firmly against the work to expose the firing pin. Neoprene traction grip stands up to grease, oil and perspiration.

Neoprene resists grease, oil and perspiration, assures a firm tool grip

Small contractors and "do-it-yourselfers" are finding the new Remington "MIGHTY-MITE" a handy tool for driving ¼" studs into steel or concrete. Just a hammer tap fires the 22 caliber cartridge, which drives the stud, anchoring wood or steel fixtures in seconds—without pre-drilling.

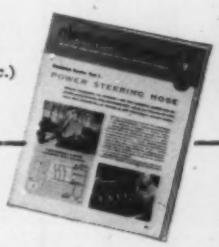
Design features of Remington's "MIGHTY-MITE" are simplicity and safety. The barrel of the tool must be twisted, then thrust down and held firmly against the work to expose the firing pin. Neoprene was selected for the barrel traction grip because of its resistance to the effects of grease, oil and perspiration. A green neoprene compound was selected because it enhanced the appearance of the finished product.

This is just one application where neoprene has proved its effectiveness. If you need a resilient material with exceptional resistance to oils, greases, solvents, chemicals, abrasion and flex cracking, it will pay you to investigate neoprene. We'll be glad to send you further information —data on properties and proven applications. If you have a specific problem, please let us know.

DU PONT
REG. U.S. PAT. OFF.

HYPALON *is a registered trademark of E. I. du Pont de Nemours & Co. (Inc.)*

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*



☐ I am particularly interested in _____

☐ Please add my name to the mailing list for your free publication, the ELASTOMERS NOTEBOOK.

Name _____

E. I. du Pont de Nemours & Co. (Inc.)
Elastomer Chemicals Department MD-5-2
Wilmington 98, Delaware

Firm _____

Address _____

City _____ State _____

How Creative Spring Engineering Aids Automation...

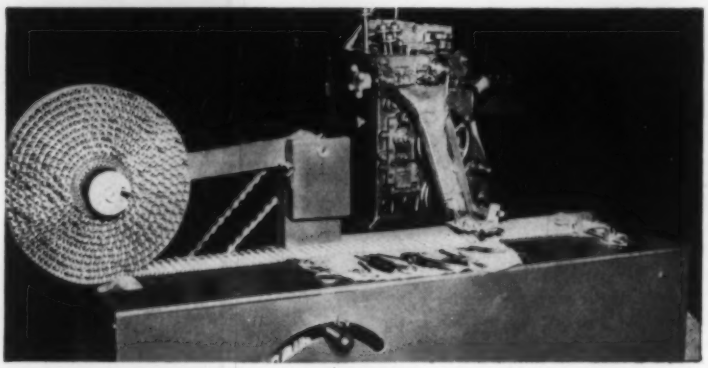
ASSOCIATED SPRING CORPORATION
COAST TO COAST

"Designed Deliveries"

engineered by Divisions of Associated Spring Corporation can be time and money savers for spring users.

Continuous coiled springs are notched at intervals—individual units broken off as needed. (Where precision ends are not required.) *Lower left corner:* Small terminal plugs supplied in strips, also notched for ease in use at assembly line.

Small open coiled springs fed from coiler into valleys of corrugated board strip. Roll at left is ready to ship—springs arrive safely—untangled.



5705
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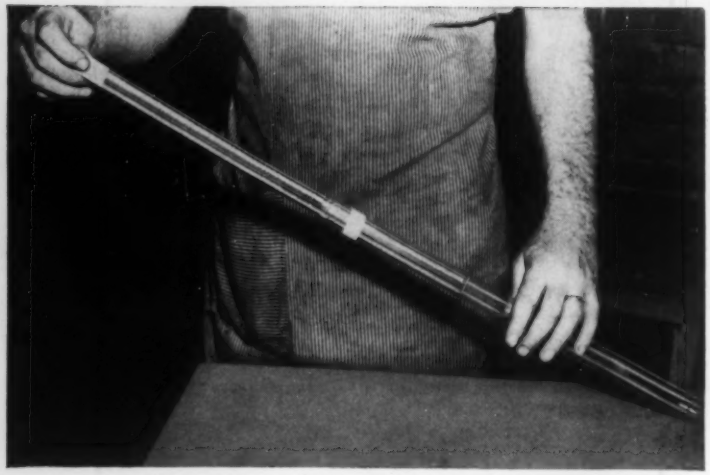
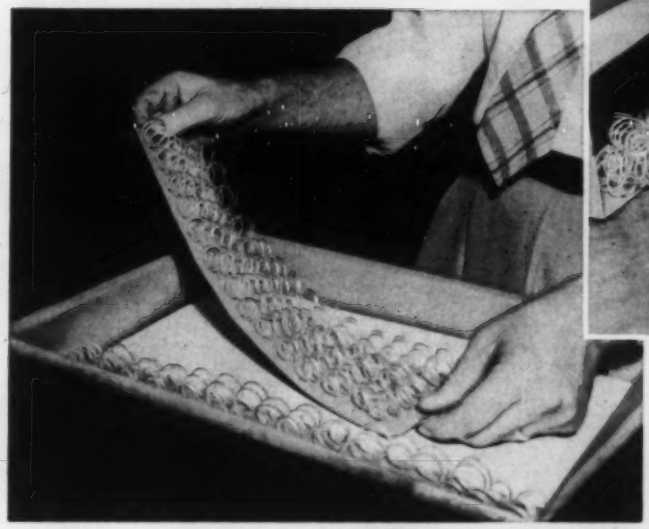
BRISTOL, CONN., U.S.A.

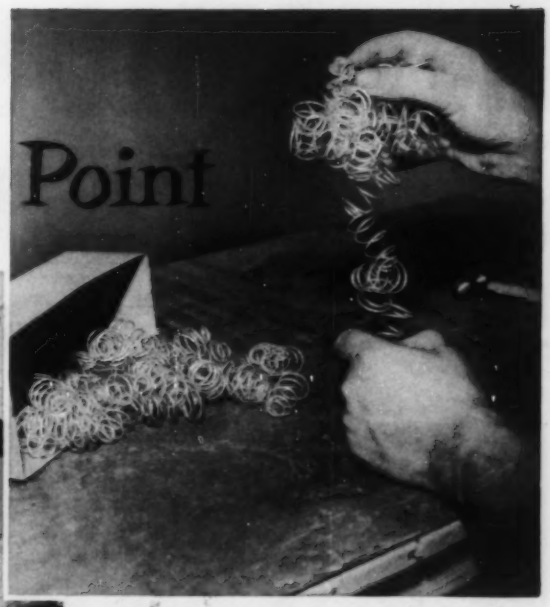


Delicate wire heater elements are caught on a flat steel strip from machine—inserted in plastic tube which protects from distortion and atmosphere. Ready for automatic feeder in customer's assembly setup.

Divisions of

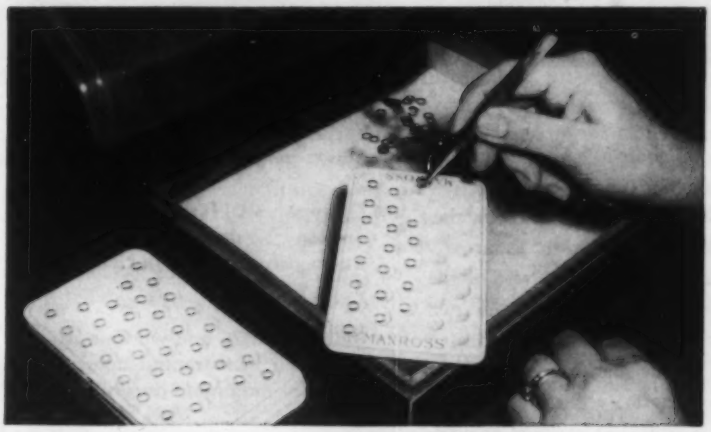
at the Assembly Point





Before-and-after views show tangle of springs in bulk shipment—and same springs held on layers of pressure-sensitive tape ready for instant selection.

Tiny hairsprings for precision electrical meters are nestled in recessed pads, avoiding distortion from contact in shipment or storage at point of use.



Do these examples suggest an approach to your spring problem? Write for pamphlet "M T M," giving further information.

DIVISIONS OF ASSOCIATED SPRING CORPORATION
COAST TO COAST

WALLACE BARNES COMPANY, BRISTOL, CONNECTICUT
THE WILLIAM D. GIBSON COMPANY, 1800 CLYBOURN AVE. CHICAGO 14.
RAYMOND Manufacturing COMPANY, CORRY, PENNSYLVANIA
BARNES-GIBSON-RAYMOND, 40300 PLYMOUTH RD. PLYMOUTH, MICH.
B-G-R COOK PLANT, ANN ARBOR MICHIGAN
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Circle 437 on page 19

New GISHOLT Turret Lathe uses compact MTS Clutches

Arrow points to one of the MTS Clutches in the lathe's headstock gear train. Close-up of MTS Clutch shown below.

When Gisholt Machine Company, Madison, Wisconsin, designed its new Masterline Saddle Type Turret Lathe, it gave clutch selection the same careful attention it gave the rest of the machine. In the final analysis, two Twin Disc MTS Clutches were chosen for use in the machine's new headstock gear train.

This is typical in machine tool design, for Twin Disc MTS and MTU Clutches (single and duplex) offer such advantages as:

- **Designed specifically for machine tools . . . with compactness a prime consideration.**
- **High torque and rpm capacity . . . with operating mechanism unaffected by centrifugal force.**
- **Single-point plate adjustment.**
- **Oil-type units, for rapid cycle operation . . . dry-type for less frequent actuation . . . in sizes from 3" to 9".**
- **Built-in quality and workmanship . . . with heat-treated operating parts for maximum durability.**

Twin Disc MTS and MTU Clutches are designed for unusually long life, easy operation and minimum maintenance. Whether you're a designer, manufacturer or user of machine tools, you'll want these sturdy, trouble-free clutches designed into your next machine . . . for the many benefits they have to offer.

TWIN DISC

Friction Clutches and Fluid Drives

TWIN DISC CLUTCH COMPANY, Racine, Wisconsin • HYDRAULIC DIVISION, Rockford, Illinois

Circle 438 on page 19

ARCHITECTURE DESIGN
MAY 30, 1957

Individual or Collective Action?

DETERMINATION of the AFL-CIO to bring engineers into "the family of organized labor" serves to sharpen the issue of professionalism versus unionism. Engineers are not so much unorganized as disorganized, but five distinct bands can be discerned in the spectrum of engineers' organizations.

At the extreme right are the conservative founder societies, such as ASME and AIEE, loosely federated with a few other technical-professional societies through the EJC at a society - management level. Next comes the NSPE, composed exclusively of registered professional engineers.

In the middle are the so-called sounding-board groups.

Next to them are the independent engineers' unions, mostly federated through the ESA. Finally, at the extreme left of the spectrum, are the engineering unions affiliated with organized labor.

With national membership from all levels, including management, neither NSPE nor the other professional societies can operate legally as collective-bargaining agencies. But they serve as clearing houses for exchange of information and ideas on professional matters including salary scales and working conditions. The professional societies also keep watch on legislation affecting engineers. In such efforts NSPE is more active than the EJC group but both groups are dedicated to co-operation between management and engineers on an individual basis.

Organized on a company basis with management participation, the sounding-board groups likewise cannot serve as certified bargaining agencies. But on a grass-roots level they perform some of the clearing-house functions that the societies do on a national scale, with overtones of local pressure and collective action.

Both union groups, with membership comprising nonsupervisory engineers, are specifically set up for collective bargaining. The ESA groups believe they can eat their cake and have it too—enjoy professional status while engaging in union tactics. NSPE and the other professional societies believe the two are incompatible.

From one end of this spectrum to the other, in the direction from right toward left, each band represents a step toward stronger collective action. And the pressures are building up for shifts in that direction. With slight changes in complexion, a sounding-board group has the makings of an independent union. And of course the AFL-CIO is anxious to bring the independent unions into the fold of organized labor.

If management can read the handwriting on the wall, the trend can be halted. Most engineers, as shown by every recent survey, instinctively look with disfavor on unionization for themselves. The decisive "no-union" vote at Minneapolis-Honeywell, reported on Page 22, should dispel any doubts on this point. Management can encourage this feeling by treating engineers as individuals, thereby making it unattractive and unnecessary for them to organize for collective action.

Colin Carmichael

EDITOR

Mechanics of Vehicles-1

By Jaroslav J. Taborek*
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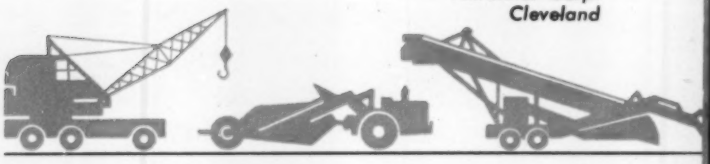


Family resemblances among "automotive" vehicles are often quite subtle. Wheels —and the fact that the vehicles are self-propelled—seem to form the sole common denominator of off-the-highway earthmovers, automobiles and fork-lift trucks, to name a few well-known members of the breed.

From the designer's viewpoint, however, vehicle differences usually prove to be matters of functional emphasis, not engineering principle. Whatever the vehicle purpose, study of forces and motions guides layout of best steering, braking and drive systems.

Mechanics of vehicle motion are outlined and correlated in this series. Terminology, for the most part, will be familiar to the engineer-owner of a passenger car. Caster, camber and toe-in, for example, are practically everyday words for describing wheel orientation with the ground.

Motion of wheels . . . control and stability . . . static and dynamic forces . . . accelerated and decelerated motion . . . performance prediction . . . these subjects form the backbone of the presentation. Emphasis throughout will be on principle rather than on specific design problems.

TRACTIVE forces for primitive transport vehicles—the oxcart is an ancient example—were externally applied. For such towed vehicles, the fundamental purpose of the wheel served admirably: while providing ground support for the body structure, it replaced high-friction sliding with the much easier rolling motion.

The self-propelled vehicle, on the other hand, demands certain additional characteristics from the rolling wheel: it is required to transform torque originating within the vehicle to a propelling thrust while, at the same time, providing high frictional resistance to side forces. This last characteristic—resistance to side thrust—permits effective directional control of the vehicle from within its structure.

Survey of vehicle mechanics begins in this article with a look at physical laws governing progression of the rigid rolling wheel. From this simple case, the analysis is extended to the more complex behavior of the flexible or rubber-tired wheel.

Rigid Wheels

Although the primary function of the wheel is to reduce friction, the existence of rolling motion depends, paradoxically, on the presence of high values of static friction. By experience, motion of a wheel takes two forms:

1. Sliding, as for any other pushed or pulled body.
2. Rolling, defined as the progressive motion of a cylindrical body in which the instantaneous contact point has no motion relative to the ground. In rolling, translatory speed of the

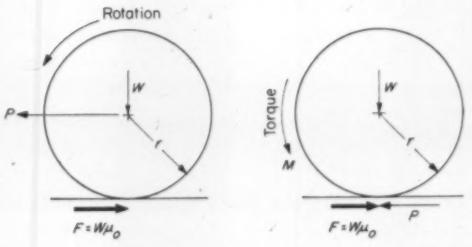
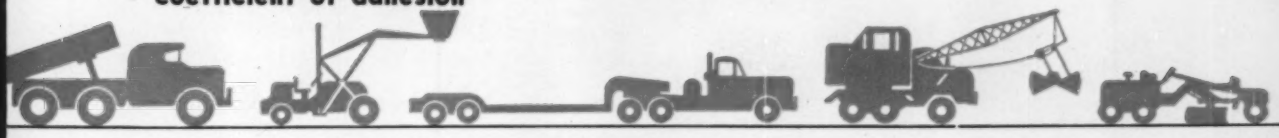


Fig. 1—Tractive force on a rolling wheel can be an external towing force (left) or result from an internally developed torque (right). Rolling continues as long as the tractive force remains within limits of the static-friction force.

*Now Research and Development Engineer, Phillips Petroleum Co., Bartlesville, Okla.

Motion of Wheels

- rolling resistance
- wheel slip
- braking stability
- coefficient of adhesion



wheel center equals the circumferential or tangential speed of the wheel rim.

The question remains: under what physical conditions can each type of motion be expected? Rolling of a wheel depends ultimately upon the existence of a static frictional force acting at the ground contact point so as to prevent the wheel from sliding. If the frictional force is too low to balance the tractive force, rolling cannot be maintained and the wheel starts to slide.

Static Friction: Coulomb's friction law offers a mathematical explanation for the rolling process and permits calculation of the limiting conditions. In equation form, the relationship is

$$F = W\mu \qquad (1)$$

The coefficient of friction μ can assume two different forms: μ_s, the coefficient of sliding friction, and μ_o, the coefficient of static friction. From equilibrium of forces, Fig. 1, and according to Equation 1, the condition for rolling motion is

$$P_{max} \leq W\mu_o \qquad (2)$$

As this equation shows, rolling motion of a wheel exists as long as the tractive force P remains smaller than the static-friction force.

Principal distinction between rolling and sliding of a wheel lies in its effective utilization of frictional ground forces. Coefficients of static friction, having higher values than coefficients of sliding friction, permit greater forces to be transmitted by a rolling wheel than by a sliding one. This is especially important during braking. The rolling wheel can also maintain its direction of travel, while a sliding wheel is directionally unstable.

The propelling force can assume two different forms:

1. External force, either pulling or pushing, acting at the wheel center.
2. Internal force, originating within the vehicle itself and translated as torque to the driving wheels. The frictional reaction of the ground is then the actual driving force.

In rolling motion it is unimportant whether the force acts on the wheel center or on its periphery. The internal traction force of a self-propelled vehicle is, however, directly limited by the available ground friction, and torque in excess of this limit is ineffective as propelling agent. Obviously, the ultimate limit on vehicle performance is set by the capacity of the wheels to create the necessary frictional connection with the ground.

Equation 2 can be rewritten to give the maximum internal torque that can be transferred to the ground by a wheel:

$$M_{max} = rW\mu_o \qquad (3)$$

Rolling Resistance: For sliding motion, the fric-

Nomenclature

B	= Braking force, lb
E	= Energy, ft-lb
F	= Frictional force, lb
f	= Coefficient of rolling resistance
f_o	= Coefficient of rolling friction, in.
g	= Acceleration of gravity, ft per sec^2
M	= Torque or moment, lb-ft
m	= Mass, lb-sec^2 per ft
P	= Propelling or tractive force, lb
R_r	= Rolling resistance, lb
r	= Rolling radius, ft
s	= Wheel slip, per cent
v	= Velocity, ft per sec
W	= Weight, lb
μ	= Coefficient of friction
μ_o	= Coefficient of static friction
μ_s	= Coefficient of sliding friction
ω	= Angular velocity, rad per sec

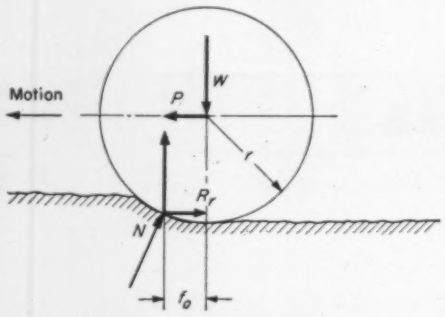


Fig. 2—Rigid wheel rolling on plastic ground. Coefficient of rolling resistance f_o has the dimension of length.

tional force $W\mu_s$ is the motion-resisting force to be overcome by traction. Static friction $W\mu_o$ is for the rolling wheel only a *limiting* force and otherwise does not participate in the actual rolling motion. The force opposing the rolling progression of a wheel is called rolling resistance.

A wheel of weight W pulled at its pivot point by a tractive force P is shown in Fig. 2. In accordance with general physical deductions on rolling resistance, the wheel, considered rigid, forms a deformation in the ground. Acting at the pressure center of the ground contact area is force N. This force can be resolved into a vertical component, forming equilibrium with wheel weight W, and a horizontal component, representing the rolling resistance R_r. Considering the height of the ground deformation negligible compared to the rolling radius r, the equilibrium equation around the action point of the ground force is

$$P = R_r = \frac{Wf_o}{r} \qquad (4)$$

Here, the proportionality factor f_o is the coefficient of rolling friction. Its value is determined by the nature of the contacting materials. Dimension of the factor is a length, which has a certain physical significance as the lever arm represented by the hypothetical horizontal distance between the point of application of the ground reaction force and the vertical axis through the wheel center (Fig. 2). Accurate measurements of f_o are difficult to make, and generally accepted data are scarce.

Elastic Wheels

Behavior of an elastic wheel, such as the rubber tire, will not exactly follow the general laws of friction and rolling that have been developed for the rigid wheel. The important difference is in the type of ground contact. On a rigid wheel, ground contact is ideally a line; on a rubber tire, it becomes a relatively large area, Fig. 3.

Rolling Resistance: Determination of rolling resistances for rubber-tired vehicles, because of wheel elasticity, requires variation in the approach developed for the rigid wheel. For the elastic wheel. Equation 4 can be written

$$R_r = Wf \qquad (5)$$

where rolling resistance R_r is simply a function of the radial weight W and of a dimensionless factor f, which is the coefficient of rolling resistance. This coefficient is itself a complicated function of the rolling radius, as well as of the materials and elastic qualities of wheel and ground.

Wheel Slip: Tests show that static friction of an elastic wheel reaches maximum, not for the theoretically required state of pure rolling, but for partial sliding. The symbol s denoting slip is introduced as a means of defining the proportion (in per cent), of sliding to rolling:

$$s = \left(\frac{v - r\omega}{v} \right) \times 100 \qquad (6)$$

where v is translatory and ωr is peripheral wheel speed.

Sliding can assume two different forms: (1) where a locked wheel is pulled over the ground (as in braking), and the translatory speed is greater than the speed of rotation ($v > r\omega$); or (2) where the wheel is turning without equivalent translatory progression (as in accelerating on slippery ground) and $r\omega > v$.

Rolling radius r is usually assumed to be the loaded radius of the tire at static nominal load. This approximation is accurate enough for performance calculations. However, the actual rolling radius will be larger due to centrifugal force effects, especially at high speeds and on low-pressure tires.

Tire Deformation: Observation of the rolling of a rubber tire on rigid ground shows that contraction of the tire surface must take place because the chord of the projected tire-contact area is

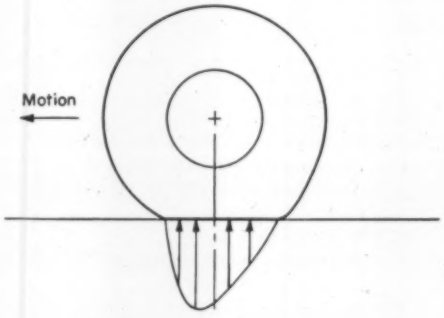


Fig. 3—Elastic wheel (rubber tire) rolling on rigid ground. Pressure distribution in the tire footprint is asymetric. Contraction of the tire periphery gives the effect of tire slip.

obviously shorter than the arc of the undeflected tire, Fig. 3. Pressure distribution in the tire footprint is shifted in the travel direction, and a pronounced surface elevation of compressed tire particles is formed behind the ground contact area. The contracted part of the tire surface will expand again after it passes the ground-contact area through the action of its elastic forces. This expansion is, in fact, a sliding motion, resulting in retardation of the translatory speed against the speed of rolling and may be called the deformation slip. Every torque transfer through a tire will therefore result in a certain slip and vice versa. Contrary to the behavior of the rigid wheel, where the highest static friction is reached with zero slip, the maximum transferable force through a pneumatic tire is reached somewhere between 10 and 20 per cent slip. According to some experimental data, 20 per cent is the limit of deformation slip, since the coefficient of friction μ_o reaches maximum at this point. Further increase of slip results in an unstable condition, with μ values falling rapidly to pure sliding value μ_s. To emphasize the particular behavior of the elastic wheel, the coefficient of friction for rubber tires has been more appropriately called *coefficient of road adhesion.*

Resultant Friction Forces: Mechanics of frictional forces on a rubber tire can be illustrated by an example. The right side of Fig. 4 is a schematic top view of a tire transferring a braking force B in the rolling direction and a side force S, perpendicular to the rolling direction. These conditions may exist, for example, in a car being decelerated on a curve. Limits of frictional forces are proportional to available μ values and are represented as circles to indicate that the tire has no preference regarding the direction of the frictional force it is transferring.

Forces B and S form a vector resultant R. As long as R stays inside the circle μ_o, rolling will exist. Should either B or S increase to the point where R cannot be contained by μ_o, the friction will fall very rapidly to μ_s values and the wheel will start to slide. Side force S, which then cannot be maintained, disappears entirely; B loses its previous direction of rolling and is opposed only to the instantaneous motion.

These considerations are significant in the braking of a vehicle. Locked wheels result in the utilization of lower μ_s values and the complete loss of rolling resistance as a decelerating force. Furthermore, and this is even more important, the locked wheel loses its ability to absorb side thrust and becomes directionally unstable.

Stability in Braking: Side thrust can be created by centrifugal force, road side elevation, asymmetrical weight distribution in the vehicle or by uneven distribution of braking forces. If, on a car equipped with four-wheel brakes, the wheels on one axle become locked, Fig. 5, these wheels lose their side thrust absorbing capacity, and all the reaction is taken by the other axle. This action results in the following stability conditions:

1. For locked rear wheels, Fig. 5*a*, inertia force mb of the moving vehicle, acts as a pushing force leaning on the front wheels. Any deviation from symmetric weight distribution will create a self-increasing turning moment around the front-axle center. The condition of locked rear wheels must, therefore, be avoided by proper brake-force distribution.
2. If front wheels are locked, Fig. 5*b*, a turning moment around the rear-axle center is produced. This is a self-stabilizing effect, since

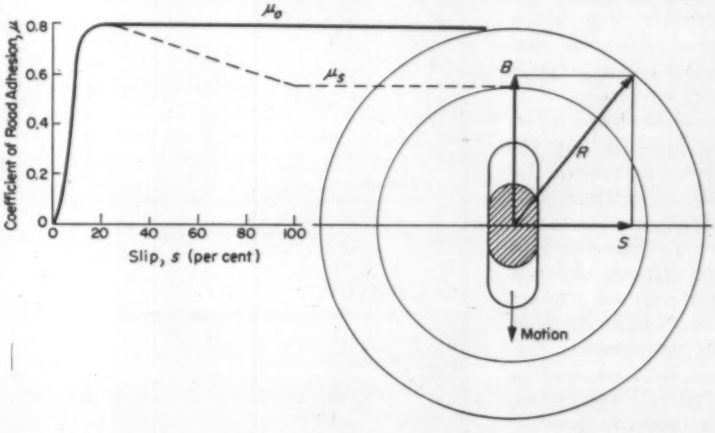


Fig. 4—Coefficient of road adhesion as a function of tire slip. Maximum ordinate value—static coefficient μ_o—is reached between 10 and 20 per cent slip. Higher angles result in an unstable condition, with tire action rapidly changing to pure slip and frictional coefficient μ_s.

View of tire footprint shows resultant R of braking force B and side force S. Circles represent forces transferable by rolling and sliding and are proportional in diameter to μ_o and μ_s. Resultant R must not exceed μ_o if rolling is to continue.

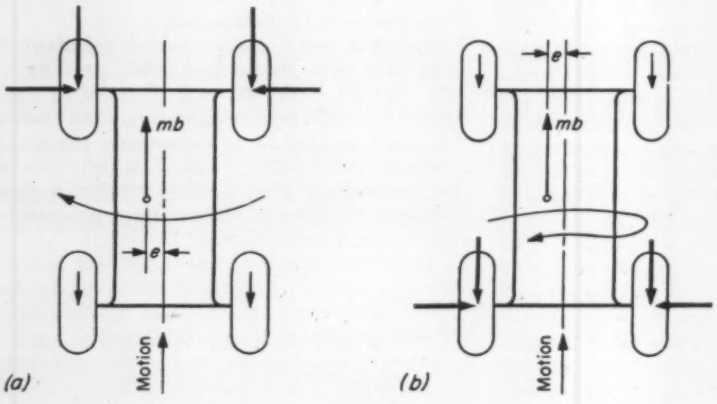


Fig. 5—Direction stability of a vehicle with four-wheel brakes. In *a*, rear wheels are locked, resulting in disappearance of the side-force reaction on the rear axle. Inertia force of the vehicle acts as a pushing force, and any asymetrical weight distribution (distance *e*) creates a self-increasing turning or skidding moment. In *b*, front wheels are locked. Inertia force acts as a pulling force with self-stabilizing effect.

the inertia force is acting as a pulling force.

Coefficient of Road Adhesion: Measurement of the coefficient of road adhesion, Table 1, is difficult and has shown great variation because of the many variables that are difficult to control and define. Nevertheless, theoretical analysis of the physical processes involved leads to better understanding of the general problem of vehicle traction.

Following are the principal factors that affect the road-adhesion coefficient:

GROUND-SURFACE MATERIAL: Asphalt, concrete and stone pavement are the usual running surfaces for highway vehicles, and their respective μ values under dry conditions are very similar. Off-the-road vehicles, however, will operate on surfaces ranging from earthen roads to deep mud and snow of varying consistency, and the undefined structure of these materials will permit μ determination only as an approximate average value.

GROUND SURFACE CONDITION: State of lubrication of the surface, usually caused by rain, is the principal factor to be considered. Widely varying μ values in the literature for wet highways are explained by the tendency of some materials, especially stone pavement and certain kinds of asphalts, to form when *slightly* wet an exceedingly slippery layer of dust and dispersed oil particles. This layer is usually washed away by heavier rain, and a new condition may be created where μ values again approach those for the dry surface.

TIRE DESIGN: The elasticity of the tire, determined mainly by the inflation pressure and the tread pattern, are the most important factors. Influence of these tire characteristics on traction is complex, and a generally accepted solution is unlikely. Certain trends, however, are apparent. Fine lamination of the tire surface delivers superior traction on a hard, smooth surface like asphalt, while for deep, soft ground (snow and mud) wide, deep diagonal ribs give the best performance. Differences in tractive performance between existing competitive products, despite advertising claims, are rather minute. Dependable technical data for comparison purposes are practically nonexistent. Of major importance is the fact that traction is usually paid for by an increase in rolling resistance and by inferior wearing properties. The practical solution is a compromise between these irreconcilable demands.

DRIVING SPEED: A definite decline of μ with increasing speed has been established. However, no specific agreement on numerical values is likely due to the intricacy of high-speed measurements under the disturbing influences of tire vibration, road shock and uplift forces.

Table 1—Average Coefficients of Road Adhesion

Surface		μ_0	μ_s
Asphalt or Concrete	(dry)	0.8–0.9	0.75
Concrete	(wet)	0.8	0.7
Asphalt	(wet)	0.5–0.7	0.45–0.6
Gravel		0.6	0.55
Earthen Road	(dry)	0.68	0.65
	(wet)	0.55	0.4–0.5
Snow	(hard packed)	0.2	0.15
Ice or Sleet		0.1	0.07

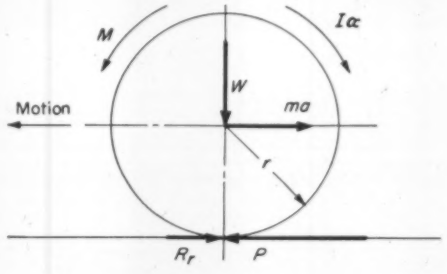


Fig. 6—Dynamics of rolling motion.

TIRE SLIP: From the function of μ versus slip (Fig. 4), two representative values are usually given, maximum friction μ_o and pure slip μ_s.

Selection of Road Adhesion Coefficient: The variety of factors influencing frictional forces, and the impossibility of accurately standardizing them usually means that only average μ values for representative conditions can be considered. Quality and condition of the surface are the important variables, while the influence of speed and tire design is normally neglected.

Choice of μ values for calculation of maximum transferable brake or traction force should be made with sufficient margin for the inevitable side forces, since the tire must transfer the vector resultant of both traction and side forces. As a safety factor, values for sliding friction μ_s are used, rather than the larger μ_o values.

Further simplification is often necessary since vehicles will operate on varying surface types. Only the general surface category (highway or off-the road) is normally established. Accepted values of μ_s for highway vehicles are between 0.6 and 0.7.

For checking strength of transmission parts and brake systems, the opposite approach is indicated, and the highest possible μ_o values are assumed. Good practice calls for the choice of $\mu = 1.0$, a value which has frequently been observed under favorable conditions.

Dynamics of rolling motion: If torque M of varying magnitude is applied to a wheel with weight W and polar moment of inertia I, Fig. 6, the resulting motion may have characteristics outlined in the following sections.

ACCELERATION: For calculation of the tractive force necessary to accelerate the wheel, use is made of the energy theorem: change in the kinetic energy of a moving body equals work performed by forces acting on the body in the drive direction. The relation is

$$dE = (P - R_r)ds \tag{7}$$

where dE is change in the energy and ds is the elementary distance. Energy of a moving wheel consists of translatory and rotating components, or

$$E = \frac{mv^2}{2} + \frac{I\omega^2}{2} \tag{8.1}$$

Consequently, after differentiation

$$dE = mv\ dv + I\omega\ d\omega \tag{8.2}$$

Substituting this result in Equation 7 and rearranging, remembering that $v = \omega r$,

$$v\ dv \left(m + \frac{I}{r^2} \right) = (P - R_r)ds \tag{8.3}$$

Since $v = ds/dt$ and $a = dv/dt$, tractive force required to produce the acceleration is then

$$P = \frac{M}{r} = a \left(\frac{W}{g} + \frac{I}{r^2} \right) + R_r \tag{9}$$

After substitution of Equation 5 into Equation 9, it can be demonstrated that the maximum acceleration that can be imposed on a rolling wheel is

$$a_{max} = \frac{W(\mu_o - f)}{(W/g) + (I/r^2)} = \frac{g(\mu_o - f)}{1 + (k/r)^2} \tag{9.1}$$

The limiting condition for this case is $P = W\mu_o$.

MOTION AT CONSTANT SPEED: In this case, tractive force will balance only rolling resistance, and

$$P = \frac{M}{r} = Wf \tag{10}$$

LIMITS OF TRANSFERABLE FORCES: Increase of tractive force above the limit set by static friction will result in sliding motion of the wheel. Sliding friction then becomes the actual motion resisting force, or

$$P = W\mu_s \tag{11}$$

BRAKING: If a decelerating or braking moment is acting on the rolling wheel, it will be aided by the rolling resistance. The maximum braking force transferable is then

$$B_{max} \leq W(\mu_o + f) \tag{12}$$

If the limits of the static friction are exceeded, the wheel starts to slide, rolling resistance as a decelerating force disappears and the maximum braking force becomes

$$B = W\mu_s \tag{13}$$

In the next part of this series, tire action in cornering, wheel-ground orientation and the mechanics of directional control will be examined.

ACKNOWLEDGEMENT

The author expresses his appreciation to R. D. Evans, Manager Tire Design Research Dept., Goodyear Tire & Rubber Co. for providing certain experimental data and reference material used in this series. Thanks are also extended to G. G. Cooper, Design Engineer, Massey-Harris-Ferguson Co. for his valuable suggestions and corrections.

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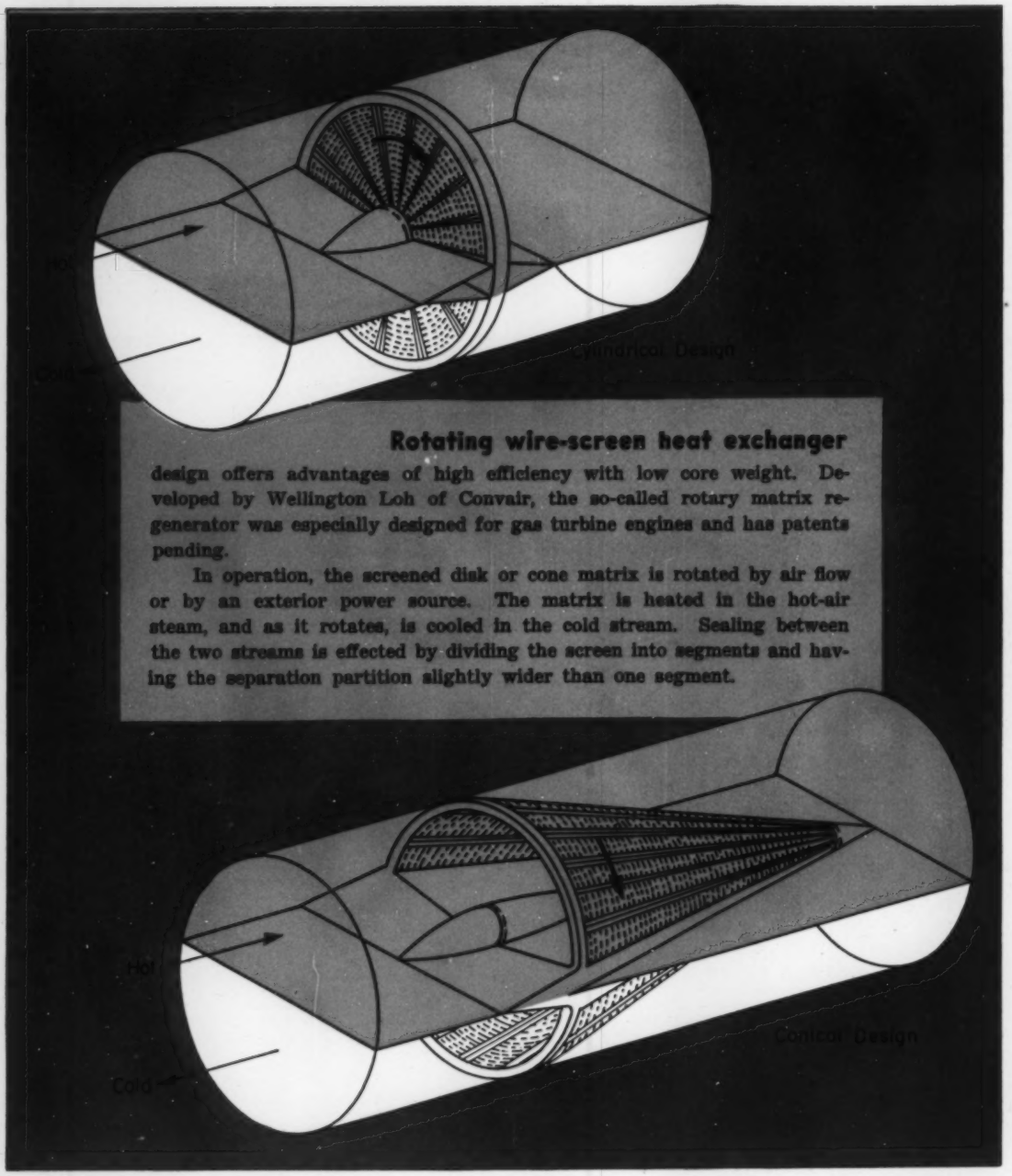
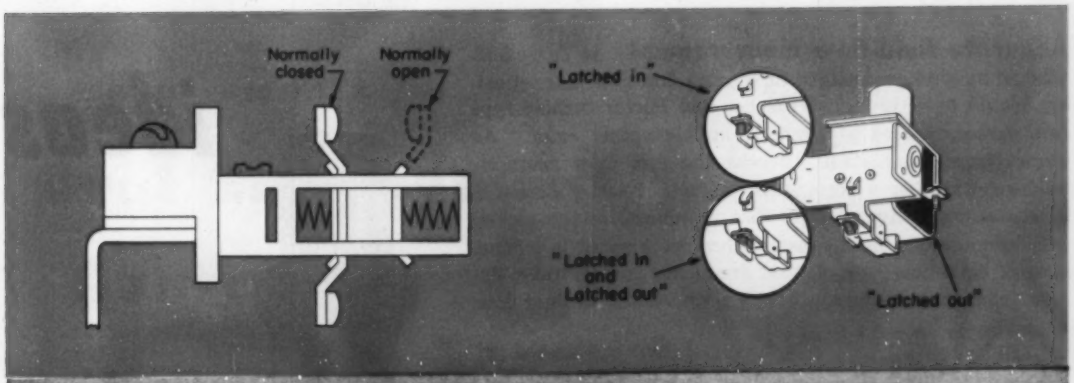
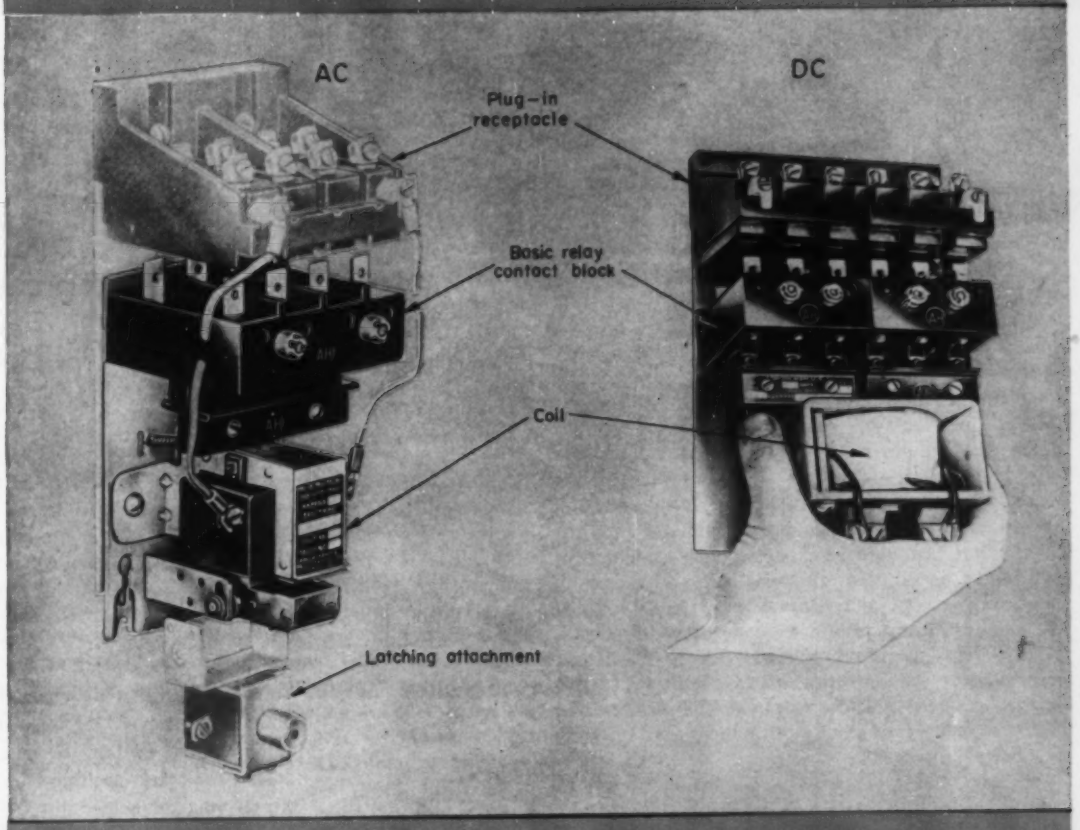
scanning the field for *ideas*



Rotating wire-screen heat exchanger design offers advantages of high efficiency with low core weight. Developed by Wellington Loh of Convair, the so-called rotary matrix regenerator was especially designed for gas turbine engines and has patents pending.

In operation, the screened disk or cone matrix is rotated by air flow or by an exterior power source. The matrix is heated in the hot-air steam, and as it rotates, is cooled in the cold stream. Sealing between the two streams is effected by dividing the screen into segments and having the separation partition slightly wider than one segment.

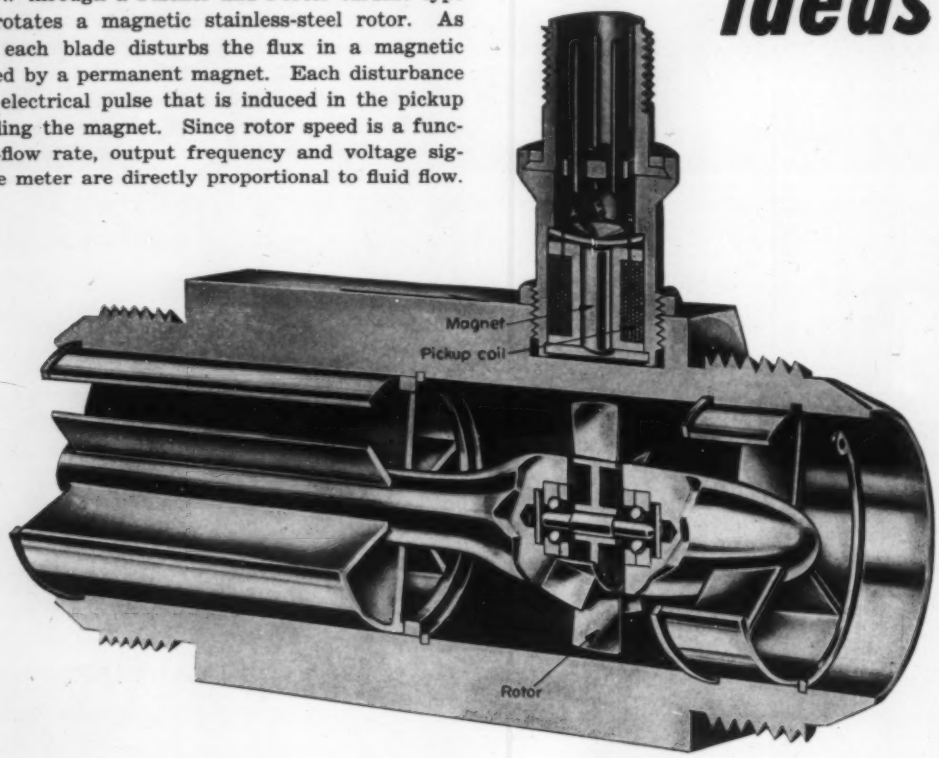




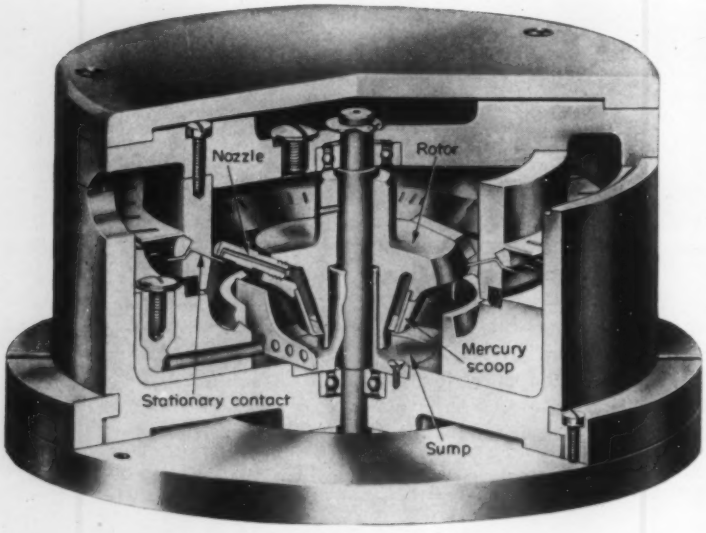
Building-block construction technique used in relay permits selection of interchangeable components to meet design requirements. Application versatility of Arrow-Hart & Hegeman Electric Co. type IMP relay design is provided by division of the assembly into four basic parts: a plug-in receptacle, a contact block, a coil, and a latching attachment. Contacts in the contact block of the basic relay are either normally open or normally closed, depending on assembled position which can be readily changed. Actuating coils, ac or dc, are interchangeable. The latching attachment can be set for "latched in," "latched out," or "latched in and latched out," depending on the position of a small latching wedge. Position of this wedge is changed by loosening one nut.

ideas

Accurate fluid-flow measurement is accomplished by a unique method of sensing flow rate magnetically. Liquid flow through a Fischer and Porter turbine type flow meter rotates a magnetic stainless-steel rotor. As rotor turns, each blade disturbs the flux in a magnetic field generated by a permanent magnet. Each disturbance produces an electrical pulse that is induced in the pickup coil surrounding the magnet. Since rotor speed is a function of fluid-flow rate, output frequency and voltage signals from the meter are directly proportional to fluid flow.



Jet-of-mercury "wiper arm" eliminates contact bounce in novel high-speed commutating switch. Design basis for the Deltaswitch, which was developed by Detroit Controls Corp., is a simple centrifugal pump. A rotor member serves as both part of the conducting path for pole contact of switch and as a pump for the mercury. Scoops on the rotor lift mercury from a pump into a rotating reservoir. Centrifugal force ejects mercury from the reservoir through a nozzle in a fine, solid stream. Sequential electrical contact occurs as rotating mercury jet strikes each one of the stationary contacts.



Requirements for

Oral Employment Contracts

By Albert Woodruff Gray
Forest Hills, N. Y.

Oral contracts come under the provisions of an old English statute that has been adopted universally in this country. This article presents a summary of court decisions on the meaning of this statute and its effect on the validity of oral employment agreements.

OVER two and a half centuries ago in England a statute was enacted that has been substantially adopted as the law in every state of this country. Known as the "Statute of Frauds," it provides in part: "No action shall be brought upon any agreement that is not to be performed within the space of one year from the making thereof unless the agreement upon which such action shall be brought, or some memorandum or note thereof, shall be in writing and signed by the party to be charged, or some other person thereunto by him lawfully authorized."

A Missouri court has said, "The Statute of Frauds is not intended to apply to written contracts but only to the enforcement of oral contracts. Its purpose is to prevent the assertion of fictitious and fraudulent contractual obligations and rights by requiring that to be enforceable certain classes of contracts must either be reduced to a written agreement signed by the party to be charged therewith, or at least be supported by a written admission by the party to be charged, of all the essential elements of the oral contract."

Performance Within One Year

A feature of this statute is that it applies only to contracts which *cannot* be performed within the year. A contract is not deprived of enforcement merely because it is possible that it *may not* be performed within the year.

"The mere fact that the contract might continue for more than a year does not bring it within the statute as, for example, where an agreement is to continue during the life of the promisee. Nor is improbability of performance sufficient if the contract is susceptible of being performed within the year.

"If the contract by its terms is not to be performed within one year it is void; but if it may by its terms be performed within a year, it is not void, even though it may not be performed or is not likely to be performed within that year.

"Nor is it necessary to take an agreement out of the statute that it should expressly stipulate that it shall be performed within the year. The possibility of such performance is enough.

"While verbal employment contracts for a year from some future date are invalid under the statute, a contract for hiring for one year without stating when the employee is to begin work, gives the employee the right to commence at once and is not invalidated because no services are performed for several days after the making of the contract."

It had been orally agreed between a commentator and an advertising agency that he would appear on weekly radio programs for ten periods of twenty-six weeks each, with a provision that the contract could be cancelled by the agency on notice in writing four weeks prior to the last broadcast of any twenty-six week period. Later the agency refused to continue the contract and advised the commentator of this decision by telegram. The commentator sued to recover what he otherwise would have received for the broadcasts for the remainder of the contract period.

The court said, "Obviously the contract in question was to run for five years but only in the event the employer did not exercise its right to terminate the same within any one of ten twenty-six week periods within the period of five years. It is clear the employer was to be bound for a longer period than twenty-six weeks only at its own discretion. Thus the reason for the statutory rule is preserved, for at no time is the employer bound for a period greater than the prescribed limitation for oral contracts."

Termination by Employee

Under an oral employment contract made in New Jersey two employees were hired for a year, their work to begin a few days later. When the employer shortly afterwards refused to assign any work to one of these employees, both left and sued

the employer for damages for breach of this oral contract of employment.

In this action, to escape the ban of the Statute of Frauds in the enforcement of their oral hiring, the employees insisted that since they had the option of quitting and ending the contract whenever they saw fit, the contract could be performed within a year and was not affected by the statute, hence they should not be denied the right to recover damages for this breach of contract.

In holding that a contract of this character could not be performed within a year and consequently was neither valid nor enforceable, the court referred to an earlier decision in that state in which the court had held, "The entire employment, being dependent upon whether the services were satisfactory, could not be entered upon until after that date and hence, if such a contract is not one contemplated by the statute to be performed within a year from its making, the contract was invalid.

Of the escape from this prohibition, urged here by these employees, that the contract was terminable at will, the court added, "Contracts for services for more than a year, subject to termination within a year at the election of a party upon the happening of some event, or even at the mere will of a party, have generally been held to be within the statute. The contemplated performance would occupy more than a year. If the contract should be terminated within a year the result would not be an alternative form of performance but excusable nonperformance."

Implied Renewal

Courts however, have refused to enforce this statute when attempts have been made to implement it to secure unfair advantages or unjust benefits. Under an oral agreement for a three-year employment, an employee was discharged after fourteen months and brought suit to recover. While the court here refused to enforce the provisions of the contract it held the employee entitled to recover for services already performed by him.

"While no action can be maintained on an oral agreement for services not to be performed within one year, such an agreement controls the rights and remedies of the parties with respect to what has been done and fixes the value of the services rendered under it when the person rendering such services is discharged after part performance without fault on his part."

This the court supplemented with the conclusion, "The parole agreement in itself and as such was and is unenforceable under the statute. If the employee had declined to enter upon the performance of his duties or if the employer had refused to allow him to render any services, no action whatever could have been maintained by either party. Both would have been remediless. So the employee's right is limited to a recovery for services actually rendered up to the time of his discharge. He cannot recover anything by way of damages for his loss of employment thereafter."

An employment contract was made on the 1st of November to continue for a year from the 21st of that month. When the employee was discharged during the following June he sued for his salary for the remaining period of the year. In its denial of recovery by this employee, since his contract for services at the time of its making was not to be performed within a year, the South Carolina court said, quoting from an earlier decision:

"This clause of the statute was intended to be applicable to contracts wholly executory and not intended on their part to be performed within a year. In other words, both the consideration and the promise must be executory and neither to be done or performed within the year. If the consideration is executed at the time the contract is made or intended to be and is performed within a year, the contract is not within the statute.

"The principle that contracts wholly executory and not intended on either part to be performed within a year are within the statute, is generally accepted as a correct construction of the statute. It will not take the contract out of the statute if it be intended that either side shall perform its part within a year."

Where, however, the employment agreement, although for one year, impliedly provides for year-to-year renewals and an employee is discharged before the end of any subsequent full year, it was held recently by a Massachusetts court that the employee is entitled to recover for the period of that year remaining after his discharge.

Similar circumstances were also the subject of a ruling by a New Mexico court. Employed as an engineer for a minimum of two years, a man was discharged at the end of fourteen months. Suit for damages for what he contended he would otherwise have earned was defended by the employer on the ground that the contract was not in writing and thus void as it was for employment for more than a year.

This law, the employee contended, did not prevent the maintenance of his suit when he had partially performed the agreement and the unperformed period was less than the prescribed year of the statute. In sustaining the dismissal of the action on the ground that in spite of these facts the statute negatived his right to sue, the New Mexico court said:

"The rule that part performance will prevent the operation of the statute so far as performance has gone, can have no application to actions for the breach of contract. In such actions recovery is based, not upon what has been done under the contract but upon the loss accruing from what has not been done.

"Therefore there can be found no ground upon which to base a right of recovery for the breach of a contract not to be performed within a year. It may consequently be stated as a rule without ex-

ception that the part performance of services under a parole contract not to be performed within a year does not remove the contract from the operation of the Statute of Frauds so that an action may be maintained for its breach."

Consideration Given by Employee

Recently an action was brought by an engineer against his employer for what the engineer claimed was a breach of his employment contract. He accepted a position at a salary of $12,000 a year and gave up a civil-service position on the promise of the employer that the position would be permanent and continue for his life.

This contract was entirely oral. In his defense to the action, the employer contended that the agreement on which this suit was based was void under the statute since it was not in writing. The Federal court in its decision in favor of the engineer said:

"The employee claims that in addition to the services to be rendered by him to this employer the latter also received a consideration in the detriment which the employee suffered by giving up a United States Government position and the civil service benefits attached to it.

"Assuming this to be true such a contract is valid and continues operating so long as the employer remains in the business and has work for the employee and the employee is able and willing to do his work satisfactorily and does not give good cause for his discharge—a discharge without good cause constituting a breach of such a contract entitling the employee to recover damages therefor. If the facts and circumstances administered that the employee furnished sufficient consideration with the intention of the parties that the employment be for life, a discharge without cause is actionable."

Then with reference to this exception of the Statute of Frauds, that employment contracts with a consideration to the employer from the employee for the award of the position are binding contracts whether oral or in writing, the court added:

"The general rule is that an oral contract for permanent employment or for life employment is not within the Statute of Frauds rendering unenforceable such contracts as are not to be performed within a year, because the contract is deemed possible of performance within one year from its formation upon the happening of various contingencies such as the death or disability of the employee within the period.

"It has been held in New York and in other jurisdictions," said that court in conclusion, "that the employee who has resigned his position with the United States Government where he had the benefits and protection of civil service and regulations for the remainder of his lifetime and under which he was entitled to certain pension and retirement rights, has furnished a sufficient consideration."

In contrast with this employment contract held enforceable, was a similar incident before the Minnesota Supreme Court. For a position in the planning and supervision of extensive improvements in a paper plant, a consulting engineer refused the offer of an assistant professorship on a college faculty. He had been assured orally by this employer that this position would be permanent with a salary of $600 a month. When two years later he was discharged he sued for $25,000 which he claimed as damages for the breach of the contract.

From a decision denying this engineer a recovery he appealed to the Supreme Court of that state. On that appeal, he argued that his contract was not within the prohibitions of this statute since his abandonment of the offer of the assistant professorship was a consideration for this employment agreement.

"The general rule," said that court, "that the assurance of permanent employment will be construed as meaning an indefinite as distinguished from a special or merely temporary employment, is the common-sense inference founded upon the common knowledge of the custom and usage of the business. The effort of this employee to show an additional consideration passing from him to his employer was abortive since it shows that he merely abandoned other activities and interests to enter into the service of this company—a thing almost every desirable servant does upon entering a new service but which, of course, cannot be regarded as constituting any additional consideration to the master."

Memorandum Contracts

The Statute of Frauds, relating as it does to oral employment contracts, has seemingly as many interpretations in the various features of the law as there are courts in the country. The solution and the means of avoiding these accumulated hazards in the contracting for engineering services, is simply an agreement in writing between the engineer and the employer, setting forth the period of employment, the compensation and the services to be performed.

In confirmation of an oral agreement, the manager of a Massachusetts company wrote the employee, "This letter will serve to confirm our agreement and understanding resulting from our conference and your acceptance of the position at a salary of $9,000 per annum beginning January 2, 1946." The contract was ended by the discharge of the employee in August of 1949. Suit was brought by him for the salary represented by the period from the date of his discharge until the end of the year. When the Massachusetts Supreme Court affirmed a judgment in favor of this employee it said,

"In our opinion the evidence was sufficient to

warrant a finding that the parties intended the employment to continue for at least a year. If it was found that the original contract was for a year we think that from a continuance of service there was an implied renewal of a contract from year to year. The Statute of Frauds was not a defense if the original contract and its renewal were for terms no longer than a year."

Another, and in many instances vital, restriction of the application of this law limiting oral employment contracts to periods less than a year, is the interpretation of the provision that the memorandum of the agreement "shall be signed by the party to be charged." In a recent case in Kentucky the contract on which the employee based his suit had been a memorandum in the handwriting of the president of the company by which he had been employed. When, ten weeks later, this employee was discharged, the employer contended that this memorandum lacked the signature required under the statute.

"The memorandum," said the Kentucky court in sustaining the right of the employee to recover, "is in the handwriting of the president of the company, is written on the stationery of the company, recites in a general way the terms of the employment and is signed 'W.C.' which are the first two initials of the president of the company. We think it meets the requirements."

Similar circumstances surrounding a memorandum before a Massachusetts court saved a suit for the breach of an agreement of this character from the prohibitions of this law.

That memorandum was, "Regarding the 5 per cent commission you spoke about—here is what we agree to do. You go along as you have on 4 per cent and for next year and after we will give you an additional 1 per cent on all shipments that go to the territory you cover."

At the end of this note was the typewritten name of the company and in the lower left hand corner were typed the initials of those dictating and typing it. Here again the memorandum was held to be signed and enforceable in spite of the contention that no action could be sustained by virtue of this old statute.

"The Statute of Frauds however, does not provide that the memorandum be the written signature of the party to be charged," asserted the court, holding this a signed contract of employment. "A memorandum is signed in accordance with the Statute of Frauds if it is signed by the person to be charged in his own name, or by his initials, or by his Christian name alone, or by a printed, stamped or typewritten signature, if in signing in any of these methods he intended to authenticate the paper as this act."

Recently, in a lawsuit involving circumstances of this character, a new Jersey appellate court summarized both the features of this statute and the wisdom of entrusting to written contracts the terms of any transactions to which it relates.

"Our Statute of Frauds," said that court, "and its prototypes have been on the books for almost three centuries but controversies still rage as to its meaning and efficacy. It was intended to guard against the perils of perjury and error in the spoken words and to protect against unfounded and fraudulent claims. In any event the policy underlying the statute and its continuance is legislative and our judicial function is to ascertain and apply it in the light of the authorities. Too many years have passed and too many pertinent decisions have been rendered to permit us to embark on our own."

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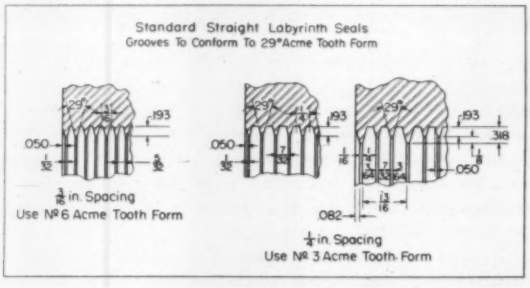
Tips and Techniques

Labyrinth Seals

When designing labyrinth teeth, either internal or external, a portion of a standard Acme thread form makes a very convenient contour. The width of the space at the bottom of the tooth and the angle of sloping side can conform to a standard Acme thread. This permits the use of a standard thread cutting tool and standard thread gages. It is usually desirable for labyrinth teeth to be



narrower than Acme-thread tooth width at the tip. This can be accomplished by varying the pitch and/or the depth of the tooth. A standard tooth gage can still be used in the root section between teeth for checking and inspection.—JOSEPH D. WALLS, *project engineer, Dresser Industries Inc., Roots-Connersville Blower Div., Connersville, Ind.*

Friction Drive for Precision Positioning

By L. A. Smitzer
Chief Design Engineer
Ditto Inc.
Chicago

Friction brakes and clutches can provide precise control of starting and stopping —if certain factors are built into the drive. Fundamental requisites are met in the design of the drive system for this office duplicating machine.

MANY times a designer is faced with the problem of starting or stopping movement in a given period (acceleration and deceleration), and also of stopping within a minimum error of a prescribed angular position.

Friction-type clutches or brakes are generally overlooked for such applications because they are "nonpositive." Positive latches, Geneva mechanisms, jaws, and cams are usually called upon first for satisfying angular position requirements.

However, if starting and stopping periods are permitted some variation, a frictional clutch system can be designed for accurate control of starting and stopping. Moreover, the advantages of smooth acceleration and deceleration can be preserved at the same time.

Achieving these desirable results, however, requires adherence to the following design factors:

1. Application of the clutch at the motor or drive end, to take advantage of high speed and low torque. The farther the clutch is removed from the driven end, and the greater the ratio between clutch speed and driven speed, the more accurate the stop and start periods will be, and the greater the load it can handle.

2. Repetitive, identical clutch action every time, eliminating operator-influenced variability in stopping and starting. A "self-energizing" triggered start engagement and a mechanically timed stop engagement are essential.

3. Precision adjustability, so that clutch operation can be matched to the idiosyncracies of a particular machine.

4. Independence of the clutch from control and drive element friction.

5. Self-adjustment for wear, to preserve initial settings and repetitive action for the life of the clutch.

Besides the foregoing performance requisites, two other objectives are always worthwhile: (1) low manufacturing and assembly costs, and (2) long life with minimum maintenance.

If these requirements guide a design, adequate precision in starting and stopping positions can be realized in many applications. How they are met in one design is outlined in this article.

An Actual Design: The foregoing general factors became specific in design of a clutch to control starting and stopping of a drum on a direct-process Ditto duplicator. In this case, the clutch was to be applied at a motor speed of 1725 rpm, controlling the stopping, starting, and rotation of a 6-in. diameter drum rotating at 105 rpm. Quiet operation of the clutch-brake was essential.

The stop was to occur within 30 deg of drum rotation, with a permissible variation of $\pm\frac{1}{8}$-in. measured on the surface of the drum (± 2 deg 23 min). In addition, the clutch was to be an independent or package unit, manufacturable within an average workmanship grade, and applicable to

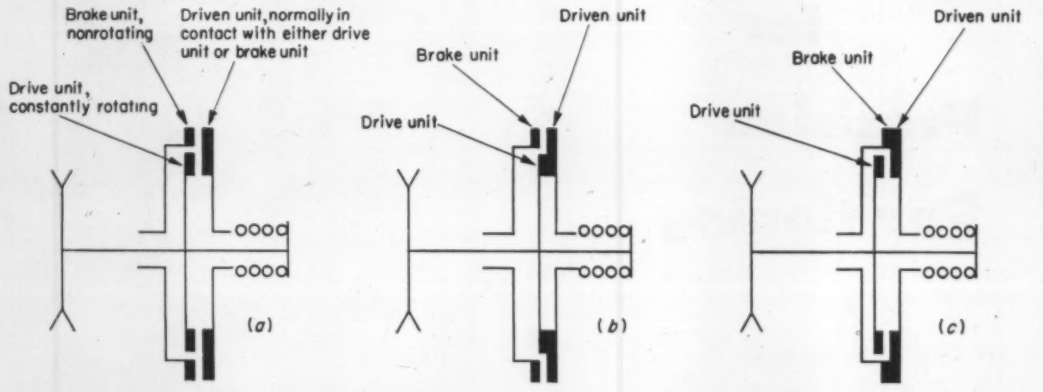
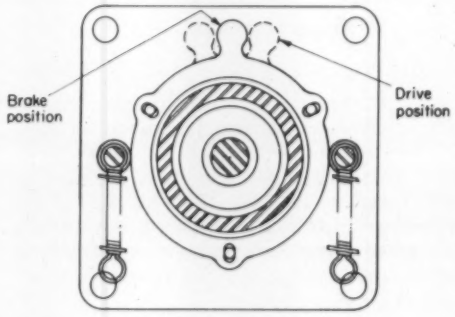
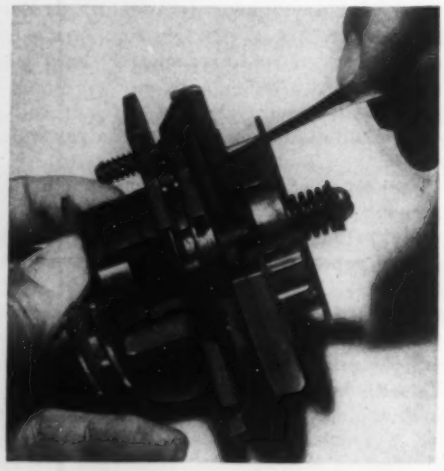
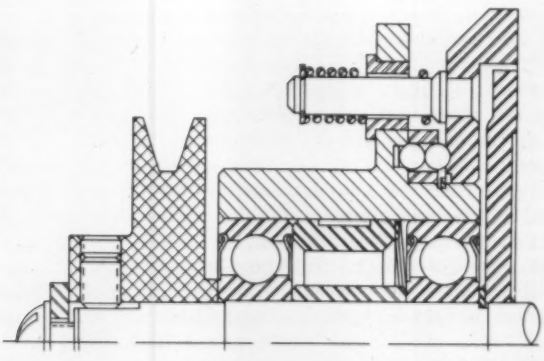


Fig. 1—Schematic of brake-clutch. Three basic parts are shown at *a*. When brake unit is retracted, *b*, spring-loaded driven unit is forced into intimate contact with drive unit. At first, slippage occurs, and driven unit is gradually accelerated to drive unit speed. Advancing the brake unit, *c*, forces the driven unit into contact with the nonrotating brake unit. With decreasing slippage, the driven unit is decelerated to zero speed.

Fig. 2 — Clutch drawing and cutaway show method of operation. As retainer plate is rotated, steel balls ride down inclined grooves coined in back of brake disk. Spring loading on studs of brake disk pull it away from clutch face. Spring-loaded clutch face is then pushed into contact with constantly rotating drive unit. In reverse action, steel balls ride up inclined grooves, forcing brake unit against clutch face, and pushing it out of contact with drive unit.







a line of electric duplicators using 1/12 to ¼-hp motors, and drums up to 18 in. long.

The fundamental design of the clutch is shown in Fig. 1. A clutch face of brake-lining material is fixed to and rotates with a driven unit. Increasing the spring pressure or coefficient of friction of the clutch face result in shorter acceleration and deceleration periods. The two areas of contact are so proportioned that their wear rates are equal or nearly so.

The brake unit, Fig. 2, consists of a hardened steel brake disk resting against three pairs of steel balls held in pockets of a molded nylon retainer plate. The plate is spring-clipped to the die-cast aluminum housing, while the balls travel on a hardened steel bearing pressure ring, which circulates the wear and prevents pockets from forming.

Limited axial movement of the brake disk is gained by rotating the nylon retainer plate so that the balls travel in three inclined coined grooves on the back side of the disk. The depth of the grooves is 1/32-in., limiting the axial movement to this same amount.

The disk is held to the housing by a spring and washer fastening on the brake disk guide studs. The studs pass through nylon wear bushings in the housing, to cushion the shock of deceleration. As a further cushion, springs attached laterally to the pins hold them against the bushings in the direction of rotation, eliminating looseness or backlash, and thus reducing deceleration impact.

This construction provides the clutch with its self-energizing start, initially actuated through the linkage shown in Fig. 3. Because of spring loading on the studs of the brake disk, the disk always presses against the balls. As the nylon retainer is rotated, the balls simply "ride down" the inclined grooves in the disk. In this manner, the retainer plate need only be triggered a distance of 5 deg before spring action takes over and carries the plate through a travel of 25 deg.

The drive unit, Fig. 2, consists of a drive shaft and disk, two ball bearings, bearing spacers, and ribbon spring.

To eliminate eccentricities and secure perfect alignment of the bearings, the nonhardened steel drive shaft is centerless ground. The large stamped disk is hydrogen brazed to the shaft, and then machined.

Inner race locking of the two ball bearings is provided by an inner bearing spacer slipped over the shaft between the bearings. Bearing preloading is gained by an outer spacer and ribbon spring pressing against the outer races.

The drive unit is completed by attaching the motor pulley to the drive shaft and fastening with a drive set screw and an axial locking screw, which locks the inner races to the shaft.

A play of 1/16-in. is allowed in the drive unit subassembly, to permit alignment of the brake and drive disk faces. This is done by first moving the nylon retainer plate to a central position and holding it with a gage. The two disks are then aligned against a common plane surface, and set screws are tightened against the outer bearing spacer of the drive unit assembly.

Thus, in drive position, the brake disk is 1/64-in. behind the drive disk. In stop position, the brake disk is 1/64-in. forward.

The driven unit consists of a lubricated, asbestos clutch face, a cast aluminum pulley, ball bearing, pressure spring and screw fastenings.

The assembled clutch is installed in a duplicating machine, and linked by timing belts to the drum. A one-hour run-in, stopping and starting each revolution, wears off any irregularities on the clutch face and provides a check on accuracy. A red stamping on the machine indicates the correct stopping point.

Deceleration variation from machine to machine may be caused by differences in the pressure spring, and by differences in the coefficient of friction. A cam adjustment compensates for this variation, and permits each machine to be stopped in the correct position, $\pm 1/8$-in.

The described design has satisfied performance requirements and has proved to be economical and to require minimum maintenance. Clutch-brake units of this design have been incorporated in all models of Ditto's direct-process duplicators.

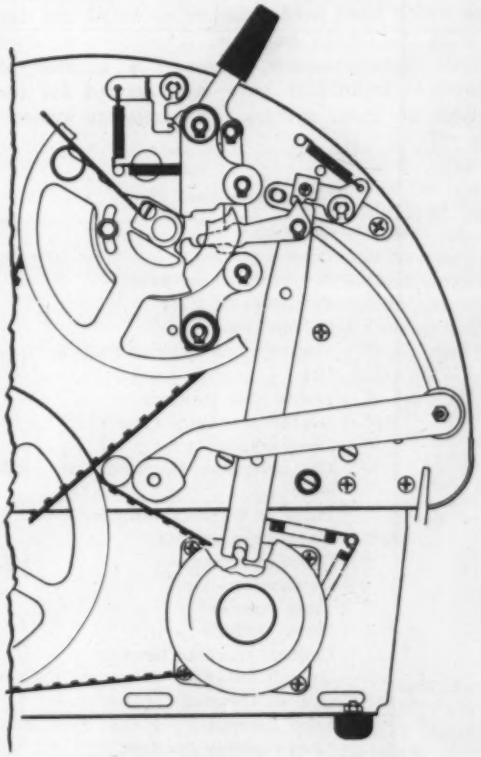


Fig. 3—Drawing of machine side shows how clutch drives drum through timing belts, and also details of the linkage that control initiation of starting and stopping.

Methods of
Improving Servo System

PART 1

- **Stability Improvement**
- **Proportional-Plus-Derivative Action**
- **Proportional-Plus-Integral Action**
- **Three-Term Control Action**

SO FAR this group of articles[1-11] has concerned the performance of simple single-loop servomechanisms. The approach has been mainly analytical. That is, investigation of the performance of systems having known component layout has been conducted by a study of the equations of the various components and of the integrated system. Occasionally this analysis has been extended to the task of optimizing certain design parameters which have been assumed to be at the disposal of the design engineer.

With transformation calculus,[2] a number of methodical techniques have been derived for the analysis of linear systems, in particular systems having a closed sequence of operation. In general a single-loop system can be represented by a block diagram of the form shown in Fig. 1. The transformed equations of such a system are

$$e(s) = \theta_i(s) - \theta_o(s)$$
$$\theta_o(s) = Y_o(s)e(s) \qquad (1)$$

The properties of transformation calculus permit algebraic manipulation of these equations — although in fact they represent differential equations with time as the variable. Therefore an overall output-input relation can be obtained:

$$\theta_o(s) = Y_c(s)\theta_i(s) \qquad (2)$$

where

$$Y_c(s) = \frac{Y_o(s)}{1 + Y_o(s)}$$

Now if the input function is specified, i.e., $\theta_i(s)$ is known, and the transfer function $Y_c(s)$ is known, the output can be found at a function of time by inverse transformation of the product $Y_c(s)\theta_i(s)$.

Because it is difficult to generalize, in the form of concise mathematical functions, the type of inputs which would likely be encountered during actual operating conditions, it is necessary to select some idealized input functions to represent typical demands on our system. One such function is the step-function input, Fig. 2. In terms of build-up time, overshoot, decay time, etc., it is possible to gain an assessment of response to sudden demands on the system.[3,4] Other idealized input functions are the impulse, or δ-function, and the velocity-step, or ramp-function. In earlier articles of this series,[3,4] some simple criteria were given for assessing such performance factors as sensitivity, accuracy and stability.

Transient Response: It will be helpful to look more closely at the factors which influence the response of a particular system to some given input function. For the moment, only a single-loop servo will be considered. Here there will be a cascade of elements in the forward path, and the

[1]References are tabulated at end of article.

Nomenclature

$A_1, A_2, \ldots B, C$	= Constants
$a, b, c, \ldots$	= Constants
$E_1(s), E_o(s)$	= Transformed voltages
$e(s)$	= Transformed error
$f(s), g(s)$	= Polynomials in s
H	= Constant multiplier of transfer function
K	= Scalar gain constant
M	= Overall amplitude ratio
N	= Loop amplitude ratio
n	= Characteristic frequency of quadratic lag
$p_1, p_2, \ldots$	= Poles of transfer function
R, C	= Network constants
r	= Order of servo
s	= Laplace operator
T	= Time constant
t	= Time variable
$Y(s)$	= General transfer function
$Y_c(j\omega)$	= Overall harmonic response function
$Y_c(s)$	= Overall transfer function
$Y_o(j\omega)$	= Loop harmonic response function
$Y_o(s)$	= Loop transfer function
$z_1, z_2, \ldots$	= Zeros of transfer function
ζ	= Damping ratio of quadratic lag term
$\theta_i(s), \theta_o(s)$	= Transformed input and output
ψ	= Loop phase angle
ω	= Real frequency variable

Performance

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loop transfer function will be the product of the transfer functions of these individual elements. The general form of $Y_o(s)$ will be

$$Y_o(s) = \frac{Kf(s)}{s_r\, g(s)} \tag{3}$$

where K is the scalar gain constant, r is a positive integer[4] normally 0, 1, 2 and rarely 3, $f(s)$ and $g(s)$ are polynomials of the form $(1 + as + bs^2 + cs^3 + \ldots)$ comprising products of factors of the form

$$1 + Ts \text{ and } 1 + 2\zeta\frac{s}{n} + \left(\frac{s}{n}\right)^2$$

As an example consider

$$Y_o(s) = \frac{K(1 + T_1 s)(1 + T_2 s)}{s(1 + T_3 s)\left[1 + 2\zeta\frac{s}{n} + \left(\frac{s}{n}\right)^2\right]} \tag{4}$$

By means of Equation 2 it is simple now to obtain the overall transfer function $Y_c(s)$, and if an input step-function, $\theta_i(s) = 1/s$, is considered,[2] there results an equation for the transformed output,

$$\theta_o(s) = \frac{Kf(s)}{s[s^r\, g(s) + Kf(s)]} \tag{5}$$

Or, taking the example given in Equation 4,

$$\theta_o(s) = \frac{K(1 + T_1 s)(1 + T_2 s)}{s(K + \alpha s + \beta s^2 + \gamma s^3 + \delta s^4)} \tag{6}$$

where

$$\alpha = 1 + KT_1 + KT_2$$

$$\beta = T_3 + KT_1T_2 + \frac{2\zeta}{n}$$

$$\gamma = \frac{1 + 2\zeta n T_3}{n^2}$$

$$\delta = \frac{T_3}{n^2}$$

First step in determining the transient response

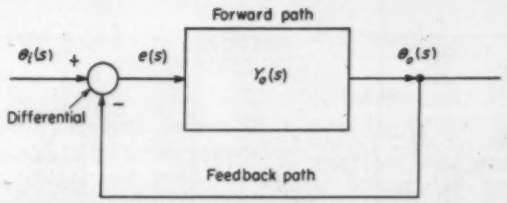


Fig. 1—Block diagram shows ordinary single-loop servo. Output is fed back and compared with input at differential.

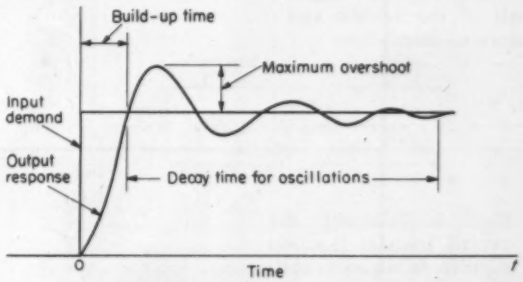


Fig. 2—Step-function input represents an idealized demand on the system. It is possible to assess performance in terms of the build-up and decay times and the size and number of overshoots.

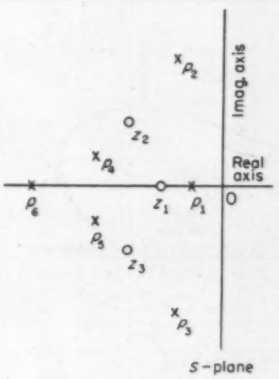


Fig. 3—The transfer function characteristics are defined if the locations of its poles and zeros in the s-plane are known. Here the poles of a typical function are denoted by crosses, and zeros by small circles. For stability all poles must lie in left-half plane.

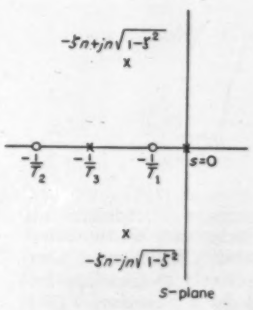


Fig. 4—The pole-zero configuration for the loop transfer function of Equation 4 is shown. It does not depend on K.

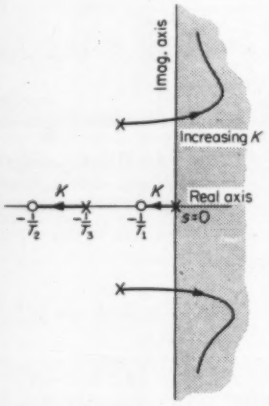


Fig. 5—Heavy lines show how the roots of the characteristic equation, or the poles of $Y_c(s)$, vary as K is increased. Note that for $K = 0$ they coincide with poles of $Y_o(s)$. Increase in K leads ultimately to a pair of complex roots crossing into the right-half of the s-plane and hence to instability.

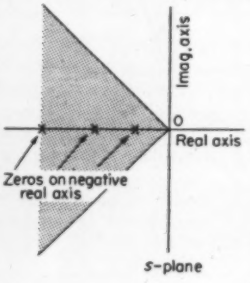


Fig. 6—Tailoring the overall transfer function to suit Whiteley's optimum parameters insures that all the poles lie on the negative real axis. Using the relative damping criterion insures that all poles lie in the shaded area.

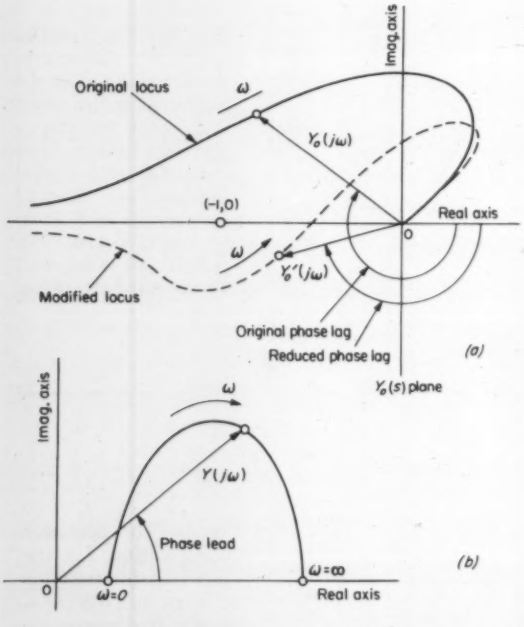


Fig. 7—The full-line curve (*a*) indicates an unstable servo. If the locus can be modified to that shown dotted, stability is achieved. One way of doing this is effectively to multiply the original function $Y_o(j\omega)$ by a function $Y(j\omega)$ having a locus as shown at *b*.

from Equation 5 is to factorize the denominator. This can be a tedious task if the degree of the polynomial is greater than three. A number of aids for the rapid computation of the roots of polynomials have been devised.[12] A summary of some of these methods will be included at a later stage in this series. Once the denominator has been factorized it is possible to rewrite Equation 5 in the form

$$\theta_o(s) = \left[\frac{H(s - z_1)(s - z_2) \ldots (s - z_m)}{(s - p_1)(s - p_2)(s - p_3) \ldots (s - p_n)} \right] \frac{1}{s} \quad \ldots\ldots (7)$$

Terms inside the square brackets represent the factored form of the overall transfer function $Y_c(s)$. The quantities $z_1, z_2, \ldots z_m$ are the values of s for which $Y_c(s)$ is zero, and are therefore called the zeros of the transfer function; $p_1, p_2, \ldots p_n$ are the values of s for which $Y_c(s)$ becomes infinite, and are called the poles; H is a constant such that $Hz_1z_2 \ldots z_m/p_1p_2 \ldots p_n = (-1)^{m-n}Y_c(0)$. The points $s = z_1, z_2, \ldots s = p_1, p_2, \ldots$ can be plotted on the s plane as shown in Fig. 3. Such a pole-zero configuration is very important, once it is known the response characteristics of the system are completely defined; the constant H merely acts as a scale changer. Note that complex zeros or poles will occur in conjugate pairs in physical systems.[2]

Equation 7 can now be expanded into partial fractions,

$$\theta_o(s) = \frac{A_1}{s - p_1} + \frac{A_2}{s - p_2} + \ldots + \frac{A_n}{s - p_m} + \frac{B}{s} \quad (8)$$

Coefficients $A_1, A_2, \ldots$ are given by

$$A_r = \left[(s - p_r) \frac{Y_c(s)}{s} \right]_{s = p_r} \qquad r = 1,2 \ldots n \quad (9)$$

Thus, for example, from Equation 7,

$$A_1 = \frac{H(p_1 - z_1)(p_1 - z_2) \ldots (p_1 - z_m)}{p_1(p_1 - p_2)(p_1 - p_3) \ldots (p_1 - p_n)}$$

The value of B is simply $[Y_c(s)]_{s=0}$. From Equation 8 the time-function output can now be obtained:

$$(Ae^{p_1t} + \ldots + A_ne^{p_nt})U(t) \quad (10)$$

The nature of each component will depend on the form of the pole $s = p_1$. This may in general be real, imaginary or complex. Only if p_1 has a negative real part will the component die away as time increases. Otherwise it will either oscillate indefinitely or else increase without limit thus giving an unmanageable or unstable system. Thus to achieve stability all the poles of $Y_c(s)$ must lie in the left-hand side of the s-plane, Fig. 3. In most physical systems the zeros, too, will all lie in this region. Where this is not so, the so-called "minimum-phase" condition is not satisfied. The significance of this will be discussed in a later article.

Stability: In determining stability it is necessary to make sure that all the poles of $Y_c(s)$, that is,

all the roots of the characteristic equation $Kf(s) + s^r g(s) = 0$, lie in the left-half plane. Now the value of each pole $p_1, p_2, \ldots$ will in general depend in a complicated way on all the parameters in the loop transfer function $Y_o(s)$. Thus in the example of Equations 4 and 6 they will be functions of T_1, T_2, T_3, ζ, n, K. The loop transfer-function itself can be expressed in terms of a constant and its poles and zeros. In Fig. 4 the pole-zero configuration for Equation 4 is shown. This is independent of K. Often K is the parameter which can be adjusted freely and the question to be asked is "how do the poles of $Y_c(s)$ move with respect to those of $Y_o(s)$ as K is varied?" An ingenious method of plotting the variation of these poles as K varies has been devised by W. R. Evans.[13] This so-called "Root-locus" method has become popular since it provides a ready means of adjusting the gain to achieve an optimum transient response. It will be reviewed in detail in a following article of this series.

A typical root locus is shown in Fig. 5. This might show for example how the poles of $Y_c(s)$ in the system of Equations 4 and 6 might vary with K. That the poles coincide with those of $Y_o(s)$ when $K = 0$ is evident from the form of the characteristic equation. Evidently a value of K is reached at which the complex poles pass into the right-half plane. This limiting value of K could easily be determined by the algebraic criteria of Routh or Hurwitz.[2] In practice, however, a value of K less than this critical value must be chosen to insure a suitable compromise between sensitivity and suitable damping. That is, a high value of K tends to speed-up the response but tends to take some of the poles of $Y_c(s)$ dangerously close to the imaginary axis, which forms the boundary between the left and right sides of the s plane. Two methods were briefly stated previously[4] for obtaining suitable values of K. Whiteley's optimum parameters insure that all poles lie on the negative real axis, Fig. 6, while the relative damping criterion insures that all the poles lie in the shaded area.

The fault with such general methods is lack of certainty that either method will give a suitable form of transient response. For instance, the Whiteley parameters, although giving adequate stability, tend to make for a sluggish response. It is preferable to treat each system on its own merits and to attempt to insure suitable transient performance in terms of its own pole-zero locations. The Root-locus method, to be discussed later, will make it possible to do just that.

Stability Improvement: The main problem facing the design engineer may be stated thus: Suppose analysis of the performance of the system shows that the highest gain which can be tolerated does not give a sufficiently sensitive or accurate system. How can response be improved without bringing on instability troubles? The last condition rules out the possibility of increasing K. It might be possible to change some of the other parameters, notably to reduce some of the time constants in the loop-transfer function. Usually, though, practical requirements do not allow more than token adjustments of these parameters. If the performance is still not good enough the system must be modified by adding elements with special characteristics. Such modifications are made for two general reasons: (1) To stabilize an otherwise unstable system, and (2) To improve the stability of a system so that K and, therefore, ac-

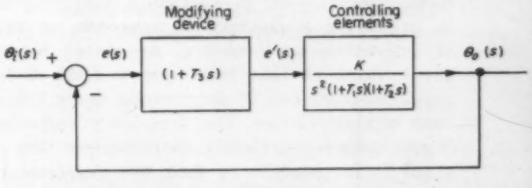


Fig. 8—Block diagram showing how modified loop transfer function is obtained by cascading controlling elements with a device having a transfer function $Y(s) = 1 + T_3 s$.

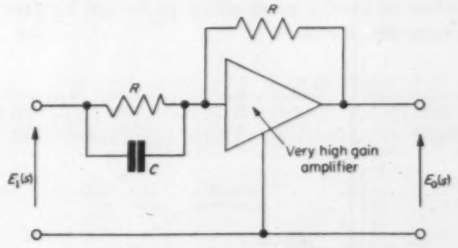


Fig. 9—The active network shown here realizes a transfer function $E_0/E_1 = -(1 + Ts)$ provided the amplifier has a very high, ideally infinite, gain.

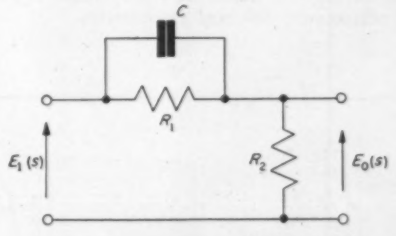


Fig. 10—This passive network gives approximately the same characteristics as the active circuit of Fig. 9. The actual transfer function is $E_0/E_1 = K_0(1 + Ts)/(1 + K_0 Ts)$, which has the desired characteristics if K_0 is somewhat smaller than unity, e.g., $K_0 = 1/20$.

curacy and sensitivity can be increased.

In attempting to improve the characteristics of a given system it is of course preferable to treat the system on its own particular merits, for instance by studying its pole-zero locations. However, it is possible to generalize on the shortcomings of closed-loop systems and there are a number of well-tried methods for overcoming them. That is to say, once it has been established that the system suffers from a defect which falls into a certain category, there are elements of known form which may be inserted into the loop to remedy the defect. This article is mainly concerned with this aspect of performance improvement. The frequency response technique has been found to be most useful both in assessing performance and in providing a methodical approach to the task of improving performance. As stated before, the great value of this technique is that closed-loop characteristics can be determined easily from open-loop characteristics. The frequency response of a linear system completely characterizes that system since it is possible to find the response to any general input function once the steady-state response to a sinusoidal input is known for all frequencies. This aspect of determining transient response from frequency response is of the utmost importance and will receive full attention in a following article. Previously a number of simple criteria for correlating the two types of response have been quoted.[3,4] These have proved by experience to give a good guide to design by frequency-response methods.

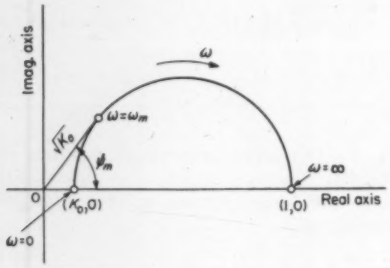


Fig. 11—Harmonic response locus for network of Fig. 10 shows how amplitude ratio and phase vary for real frequencies.

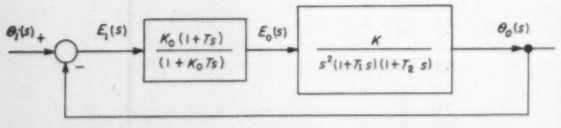


Fig. 12—Here a loop transfer function which would yield an unstable closed-loop system is cascaded with a passive phase advance network. By this device the system can be made stable provided a suitable value for K is selected.

The loop harmonic response function $Y_o(j\omega)$ can be found simply by putting $s = j\omega$ in Equation 3. A servo discussed at the end of Reference 11 was found to have a harmonic response function of the form

$$Y_o(j\omega) = \frac{K}{(j\omega)^2(1 + j\omega T_1)(1 + j\omega T_2)} \qquad (11)$$

A plot of this function, Fig. 7*a*, shows the system to be inherently unstable since the critical point $(-1, 0)$ lies to the right of the contour as ω increases. The aim here must be to modify the function $Y_o(j\omega)$ and still retain the zero-velocity-error characteristic—in other words the $(j\omega)^2$ term must be retained in the denominator, so that the curve must still be asymptotic to the negative real axis at low frequencies.

Stability will be insured if the locus is modified to the dotted form in Fig. 7*a*. Effectively, $Y_o(j\omega)$ has been multiplied by a vector $Y(j\omega)$ whose locus is plotted in Fig. 7*b*. The main characteristic of this function is that it has a positive phase angle —lead—rather than the negative phase angle—lag —of most components so far discussed. A function having such a leading phase is

$$Y(j\omega) = 1 + j\omega T_3 \qquad (12)$$

Multiplying the original loop function by $Y(j\omega)$ gives a new function

$$Y_o'(j\omega) = \frac{K(1 + j\omega T_3)}{(j\omega)^2(1 + j\omega T_1)(1 + j\omega T_2)} \qquad (13)$$

Note that the $(j\omega)^2$ term is retained in the denominator; hence there will still be zero velocity-error. Stability is now conditional, depending on the critical point $(-1, 0)$ lying to the left of the contour as in the dotted curve of Fig. 7*a*. The limiting value of K for stability can be found algebraically. The characteristic equation now is $1 + Y_o'(s) = 0$, and here this is

$$T_1T_2s^4 + (T_1 + T_2)s^3 + s^2 + KT_3s + K = 0$$

Now the Hurwitz criterion for stability (Equation 15, Reference 3), gives

$$K \leqq \frac{(T_3 - T_1 - T_2)(T_1 + T_2)}{T_1T_2T_3^2} \qquad (14)$$

If $T_3 > (T_1 + T_2)$, the system can be made stable by adjusting the loop gain constant K. In practice the suitable value of gain would be somewhat less than that given by the equal sign in Equation 14 in order to insure a well-damped system. One method[4] of securing a satisfactory K would be to limit the maximum value of M to 1.3-1.5. The problem here would be to find a suitable value of K and T_3 to insure this condition.

Proportional-Plus-Derivative Action: The modified loop function $Y_o'(j\omega)$ can be obtained by cascading, with the elements in the forward path, a device having the transfer function $Y(s) = 1 + T_3s$, Fig. 8. In effect the controlling elements of the system are now sensitive to a modified signal e' which is equal to the error e plus a term pro-

portional to the derivative of the error, $T_3 de/dt$. Physically this means that the system is sensitive not only to an error, when it occurs, but also to the rate of change of the error. Therefore the system gets warning of any rapid build-up of error and can take effective correction before the error has a chance to build up to any appreciable value. This action is sometimes spoken of as "anticipation" control, although this choice of terminology is rather misleading. Another term used is "proportional-plus-derivative" action: This name is self explanatory—it is in common use in the process control field.

The general effect of phase advancing on stability can conveniently be described in terms of the frequency response. The phase lead delays the frequency at which the loop phase angle becomes −180 degrees. This gives the amplitude ratio N a chance to decrease further due to time delays in the control elements, and if $N < 1$ when the locus cuts the negative real axis, in general the system will be stable.

The effect of phase advance on the overall frequency response is that it tends to reduce the overall phase lag between θ_i and θ_o—that is, it tends to equalize the output and input phases. For this reason such devices are sometimes called "equalizers."

The problem now arises: how to realize the device giving the special frequency characteristic—in this case phase advance. The answer is to design networks of elements to give the desired characteristics. This is probably easiest when the networks will consist of electrical elements, particularly if they are passive, since construction is simple and the element characteristics are reliable. It is normal practice to put these networks in the low-power side of the system; conveniently they may be interstage networks in electronic preamplifiers.

It is possible to synthesize networks having almost any kind of frequency characteristic, particularly if active elements can be included. This aspect will be covered in later articles. However, there are a number of well-known standard forms giving special kinds of characteristics. These will now be briefly mentioned.

To realize Equation 12, a network capable of differentiating a signal will be needed. This can only be done reasonably well with an active circuit having a high-gain amplifier. Thus the circuit shown in Fig. 9 will give a transfer function of the form

$$\frac{E_0}{E_1}(s) = -(1 + Ts) \tag{15}$$

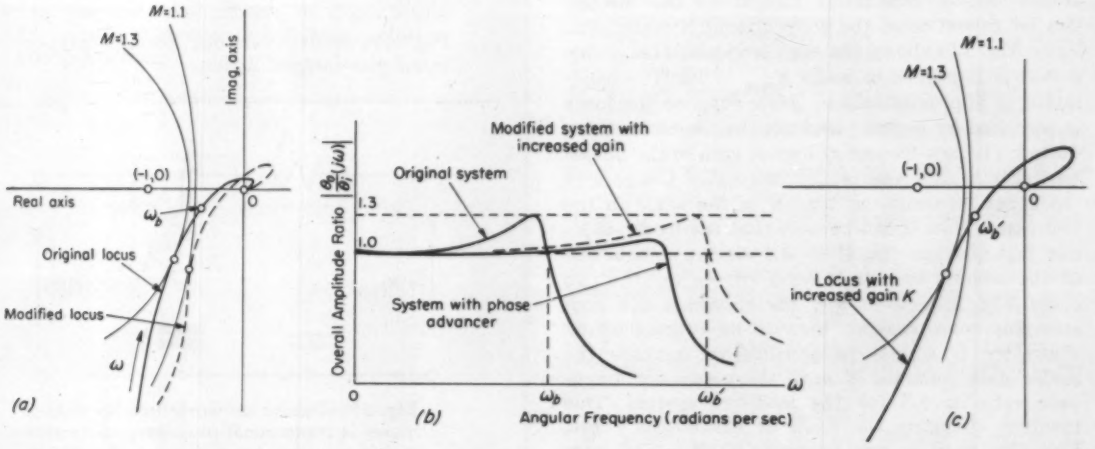
Where $T = RC$. This is of the right form except that there is a reversal of sign between input and output.

Passive Phase-Advance Networks: Although it is not possible to get true differentiation using passive networks, it is possible to devise passive networks exhibiting phase-advance properties. Probably the simplest of these is the circuit shown in Fig. 10. The harmonic response function of this is

$$\frac{E_0}{E_1}(j\omega) = K_0 \frac{1 + j\omega T}{1 + j\omega K_0 T} \tag{16}$$

where $K_0 = R_2/(R_1 + R_2)$, $T = R_1 C$. Now if K_0 is considerably less than unity, the effect of the lag in the denominator will be less than the lead

Fig. 13—The locus of a stable servo is shown (*a*) together with a locus modified by the use of a phase advancer. Overall amplitude ratio curves (*b*) show that the maximum amplitude ratio is reduced from 1.3 to 1.1. With the phase advancer, the net loop gain constant K can be increased to bring the maximum amplitude ratio back to 1.3, (*c*). This results in the bandwidth being increased, giving improved accuracy and sensitivity without affecting stability unfavorably.



in the numerator over the lower frequency range so that there will be a net phase lead. As the frequency becomes large, however, the lag in the denominator will gradually cancel out this lead. Note that if K_0 is less than unity there will be a reduction in the loop gain constant of the servo if this network is cascaded with the other elements. In order to bring the gain back to its original value the gain constant of some other element in the loop must be increased in the ratio $1/K_0$.

The locus of the function given by Equation 16 is plotted in Fig. 11. Maximum angle of phase advance occurs at frequency

$$\omega_m = \frac{1}{T\sqrt{(K_0)}} \qquad (17)$$

and is given by

$$\psi_m = \tan^{-1}\left[\frac{1 - K_0}{2\sqrt{(K_0)}}\right] \qquad (18)$$

The corresponding amplitude ratio is given by

$$\frac{E_o}{Ei}(j\omega_m) = \sqrt{(K_0)} \qquad (19)$$

Suppose such a network is cascaded with the forward elements of the unstable system given by Equation 11 (see Fig. 12). The modified loop transfer function is now

$$\frac{\theta}{e}(s) = Y_o'(s) = \frac{KK_0(1 + Ts)}{s^2(1 + T_1s)(1 + T_2s)(1 + K_0Ts)} \qquad (21)$$

This can again be made stable if correct values of K, K_0, T are chosen. Choice of network constants usually involves some tailoring to suit the system as a whole, and in this respect the use of logarithmic plots, to be described in the next article, is very helpful. Normally the sort of value chosen for K_0 is about 1/20 giving a maximum phase lead of 65 degrees.

The use of lead networks to improve the performance of a system can also best be approached with the aid of logarithmic plots if it is desired to obtain quantitative values for the network constants. But a qualitative insight to the method can be gained from the conventional Nyquist plot. Thus Fig. 13*a* shows the open-loop plot of a stable servo; K is chosen to make $M_{max} = 1.3$. The bandwidth is approximately ω_b. Now suppose the locus is modified by a phase-lead network to that shown dotted. The low-frequency loss of gain in the phase-advancer is compensated by increasing the gain of the other elements, so that K is the same in the two cases. Now it can be seen that the modified locus just touches the $M = 1.1$ circle; comparison of the overall amplitude ratio curves for the two cases, Fig. 13*b*, shows that the system is now considerably more damped than in its original state. Therefore it should be possible to increase the scalar gain constant K until the maximum amplitude ratio is 1.3 for the modified system. This involves changing the scale of the dotted curve, Fig. 13*a*, until it just touches the $M = 1.3$ contour, Fig. 13*c*. Here the scale has been increased approximately twice so that the scalar gain constant K can be multiplied by two.

A great advantage thus achieved is that the steady-state error when following a unit velocity input[4], is only half of that for the original system; remember that the velocity error is $1/K$ for a first order system. Yet another improvement is apparent. The locus now touches the $M = 1.3$ contour at a higher frequency than before so that the bandwidth of the overall response has been increased, see dotted curve Fig. 13*b*. Increase of bandwidth means that the speed of response has been stepped up.

Thus by using the phase-lead device it has been possible to increase the gain constant K to improve both the accuracy and sensitivity of the servo.

Proportional-Plus-Integral Action: Another useful modifying network has a transfer function of the form

$$\frac{E_0}{E_1}(s) = K\left(1 + \frac{1}{Ts}\right) \qquad (21)$$

An active network which will realize this characteristic is shown in Fig. 14. The network produces as its output the sum of two terms, one proportional to its input and the other proportional to the integral of the input with respect to time. Such a device is said to give proportional-plus-

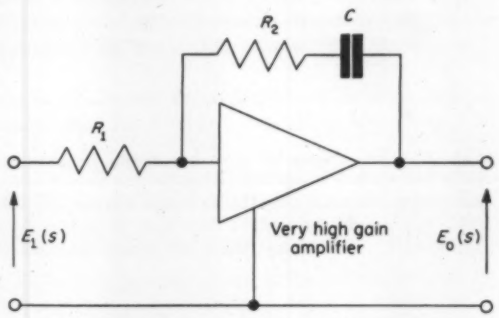


Fig. 14—Active network realizes proportional-plus-integral action.

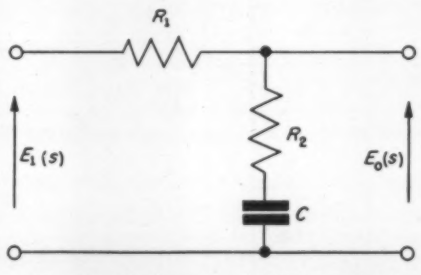


Fig. 15—Passive network here approximates proportional-plus-integral control if elements are correctly valued.

integral action, for obvious reasons. To understand the action of the device it is convenient to work here in terms of frequency response. Thus, writing $s = j\omega$ and $K_1 = K/T$, it is possible to write the harmonic response function in the usual convention, thus

$$\frac{E_0}{E_1}(j\omega) = \frac{K_1(1 + j\omega T)}{j\omega} \tag{22}$$

What will be the effect of introducing such an element into a typical system? Suppose that the system has the loop response function

$$Y_o(j\omega) = \frac{K}{j\omega(1 + j\omega T_1)} \tag{23}$$

This is unconditionally stable, but with a finite velocity-error of $1/K$, since the order is one. Now if the modifying network is included in the forward path the modified response function is given by

$$Y_o'(j\omega) = \frac{KK_1(1 + j\omega T)}{(j\omega)^2(1 + j\omega T_1)} \tag{24}$$

The order of the system is two; hence there is zero velocity error. Investigating stability, the characteristic equation becomes

$$T_1 s^3 + s^2 + KK_1 Ts + KK_1 = 0 \tag{25}$$

The criterion for stability is now $KK_1T \geqslant KK_1T_1$, or simply $T \geqslant T_1$, Equations 10 and 12, Reference 3.

Obviously the network has not only raised the order by one to eliminate the velocity error but has also provided the necessary phase advance term in its numerator to insure stability. The passive network shown in Fig. 15 gives approximately the same characteristic as the active circuit in Fig. 14, provided the components are chosen suitably, except at low frequencies. Even if zero velocity-error cannot be truly achieved it is possible to reduce it considerably.

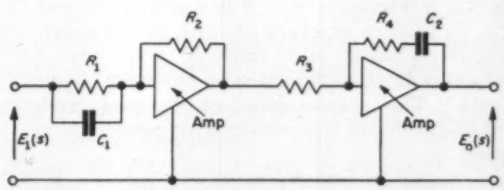


Fig. 16—Cascaded devices of Figs. 9 and 14 give proportional-plus-integral-plus-derivative action.

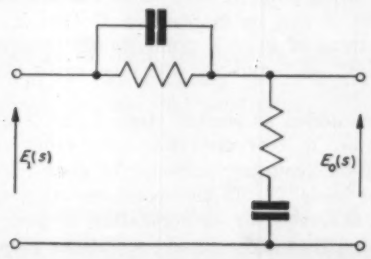


Fig. 17—This passive network can approximate characteristics of system shown in Fig. 16.

Three-Term Control Action: Another well-known circuit consists of the devices of Figs. 9 and 14 in cascade, Fig. 16. This is the so-called "three-term control action" or "proportional-plus-integral-plus-derivative" action. In terms of time functions the output is given by

$$e_o(t) = Ae_1(t) + B\int_0^t e_1(t)dt + C\frac{de_1(t)}{dt} \tag{26}$$

This can again be expressed in conventional form by

$$\frac{E_0}{E_1}(j\omega) = \frac{K(1 + j\omega T_1)(1 + j\omega T_2)}{j\omega} \tag{27}$$

Placed in the forward path of a servo this device again increases the order of the system by one and also introduces phase advance terms—two this time—in the numerator of the transfer function. In Fig. 17 a passive network is shown which will approximate the characteristics of Equation 27 if its elements are suitably valued.

Although only electrical networks have been considered here for providing the necessary modifying characteristics, there is no reason why similar mechanical or hydraulic networks cannot be devised to give the same functions. Some of the special problems involved here will be discussed in a later article.

REFERENCES

This article is the twelfth in a co-ordinated group by J. M. Nightingale on servo systems. The previous articles and the issues of MACHINE DESIGN in which they appeared are:

1. "Automatic Control Systems".....May 17, 1956
2. "Servo Mathematics".....June 28, 1956
3. "Evaluating Servo System Performance—Part 1"..July 26, 1956
4. "Evaluating Servo System Performance—Part 2"..Aug. 9, 1956
5. "Analyzing Servo Systems".....Nov. 1, 1956
6. "Hydraulic Servo Components—Part 1".....Nov. 29, 1956
7. "Hydraulic Servo Components—Part 2".....Dec. 13, 1956
8. "Hydraulic Servo Components—Part 3".....Dec. 27, 1956
9. "Hydraulic Servos—Part 1".....Feb. 21, 1957
10. "Hydraulic Servos—Part 2".....March 7, 1957
11. "Hydraulic Servos—Part 3".....March 21, 1957

Other references mentioned in the current article are:

12. Rufus Oldenburger—"Practical Computational Methods in the Solution of Equations," *American Mathematical Monthly*, Vol. 45, June-July, 1948, Pages 335-342.
13. W. R. Evans—*Control System Dynamics*, McGraw-Hill Book Co., New York, 1956.

REPRINTS

Articles listed above by J. M. Nightingale are now available in reprint form. Articles 1 to 5 are contained in Volume 1 (32 pages) and articles 6 to 11 in Volume 2 (32 pages) of "Hydraulic Servo Fundamentals." The volumes are available at $1.00 each from Reader Service Dept., MACHINE DESIGN, Penton Bldg., Cleveland 13, O.

ERROR

In Article 10 above, Equation 30 was in error. It should be: $K = (b/2)\sqrt{(\lambda_v X_o/A^3)}$.

Designing

Gear-Train Limit Stops

for control of shaft rotation

By F. Freudenstein*, K. L. Warthman and A. B. Watrous
Consultant *Technical Staff*
Bell Telephone Laboratories
Whippany, N. J.

IN THE design of gear trains for control mechanisms and other similar applications, rotation of a particular shaft must often be limited to some predetermined angle. If the angular travel of the slowest shaft in such a train is more than one revolution, the means for limiting the excursion poses a minor design problem. This article presents a useful step-by-step design procedure for one practical arrangement of multiple-turn stop to meet such requirements.

When the rotation of one of the train shafts is less than 360 deg, a simple fixed stop, Fig. 1, is satisfactory. However, for limiting rotations of more than a full revolution, other means, such as a traveling nut or tabbed washers, can be employed. While these methods are satisfactory in many instances, they may be difficult to use when space is at a premium, when many shaft revolutions are required between stops, or when close control of the end limits is necessary.

Another practice which does not have these disadvantages utilizes stop pins on each gear of a single mesh in which the gears are unequal in size and the number of teeth of one is not a multiple of the other. The following discussion deals with a procedure for determining the size of the stop pins and/or the size of the gears needed in this type of stopping arrangement.

Basic Principles: In the arrangement shown in Fig. 2, gears 1 and 2 are of such size that

$$\frac{N_1}{N_2} = C + R \qquad (1)$$

where C is a whole number, R is a remainder, and N_1 and N_2 are the numbers of teeth in the gears. That is, N_1 is not an exact multiple of N_2. Such a pair of gears is often described as having a "hunting tooth." This characteristic of the gear mesh is used to advantage in the stop arrangement being discussed.

Assume $N_2 = 36$ and $N_1 = 2(36) + 9 = 81$, Fig. 2. Consider points A and B, which are on the line of centers as shown in the starting position. For one revolution of gear 1, the number of turns of gear 2 is: $N_1/N_2 = 81/36 = 2\frac{1}{4}$ turns or 2 turns plus 9 teeth.

Therefore, when point A returns to the starting position, point B will be in position B'. For 2, 3, and 4 revolutions of gear 1, point B will progress to positions B'', B''' and B, with the cycle then repeating.

If stops are added as shown, stops 1 and 2 will permit rotation in one direction only from the starting position (counterclockwise for gear 1 and clockwise for gear 2). If the positions of stops 2 and 4 are observed for each rotation of gear 1, it will be noted that after three revolutions stop 4 will reach the dotted position in contact with stop 3, and rotation will cease.

This simplified illustration demonstrates an ar-

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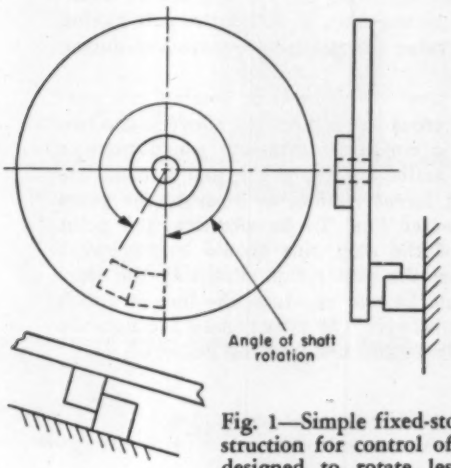


Fig. 1—Simple fixed-stop construction for control of shafts designed to rotate less than one revolution.

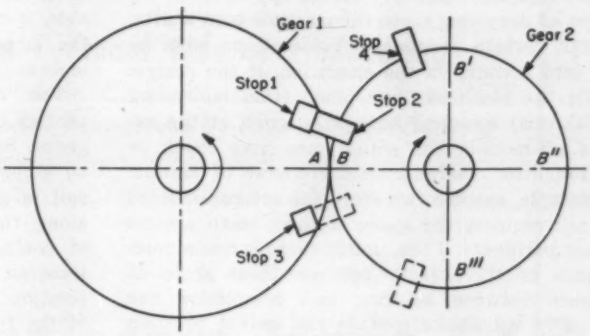


Fig. 2—Multiple stop arrangement for limiting shaft rotations of more than one revolution.

rangement which permits three revolutions of gear 1 and 6¾ revolutions of gear 2. In practice, the stop pins would be combined so that only one pin would be required on each gear. For instance, in the example discussed it can readily be seen that stops 1 and 2 (if appropriately shaped) would come into contact somewhere after 3¾ revolutions of gear 1. Thus, only one set of stops would be necessary.

Design Calculations: Before the multiple-turn stop-pin arrangement can be applied, it is necessary to determine the number of teeth required on the gears to obtain the desired angular travel. The following procedure has been found useful.

If ω_1 is the required number of revolutions of shaft 1, then

$$N_1 \omega_1 = M_{12} \qquad (2)$$

where M_{12} is the lowest common multiple of the numbers of teeth on gears 1 and 2. In addition, it can be demonstrated that the foregoing relationship imposes four conditions:

(1) $N_2 \geqq \omega_1$
(2) N_2 is a multiple of ω_1
(3) N_1 is a multiple of N_2/ω_1
(4) Highest common factor of N_2 and N_1 is N_2/ω_1

The following examples illustrate how these relationships can be used to solve some typical problems.

EXAMPLE 1: A shaft, on which is mounted a 96-tooth gear, is required to rotate 19 turns between stops. Determine the size of the mating gear, which cannot contain more than 100 teeth.

Basic data are: $N_1 = 96$, $\omega_1 = 19$. From the foregoing conditions 1 and 2, N_2 can be 19, 38, 57, 76, or 95. However, condition 3 eliminates the possibility of $N_2 = 95$. The four remaining values of N_2 satisfy condition 4 so they may be used. They also satisfy Equation 2, which may be used for checking if desired.

EXAMPLE 2: Two meshing gears have 27 and 42 teeth. Find the least number of turns the larger gear can make between stops. Factoring the numbers of teeth in the gears gives $27 = 3(3)(3)$ and $42 = 3(2)(7)$. Combining these groups of factors to find the lowest common multiple yields: $M_{12} = 3(3)(3)(2)(7) = 378$. From Equation 2, $N_1\omega_1 = 378$ and $\omega_1 = 378/42 = 9$.

EXAMPLE 3: If $\omega_1 = 19$ and $N_2 = 24$, find N_1. From condition 2, N_2 must be a multiple of 19. Since this is not so, solution is impossible for this method of approach.

EXAMPLE 4: Given design data are: $\omega_1 = 19$, $N_2 = 57$. Determine N_1. From condition 3, N_1 must be a multiple of 3. From condition 4, the highest common factor of N_1 and N_2 is 3. Since the only other factor of $N_2 = 57$ is 19, N_1 cannot be divisible by 19. Thus, N_1 can have values of 3, 6, 9, 12, etc., so long as the number is divisible by 3 and not by 19.

Practical Limitations: The preceding method of

analysis is a theoretically correct approach to the problem of designing stops for multiple-turn shafts. However, certain practical considerations must be taken into account in the execution of the design.

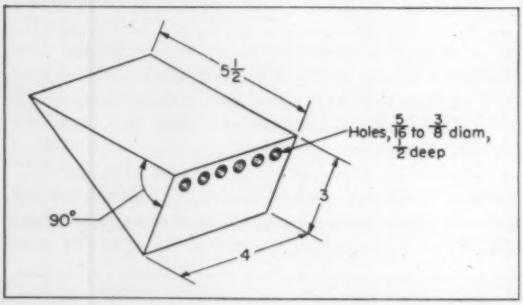
While the idealized "line pins" (that is, having no thickness) assumed here only touch at the extremes of motion, the actual pins may touch or have too little clearance in the course of motion. For example, assume two stop pins are constructed and each requires the space of three teeth around the gear periphery. Then, unless there is a minimum clearance of three teeth between these stops at all times between starting and completing the cycle, they will make contact and arrest rotation too soon. A simple way to check this separation of the idealized line pins is by checking for the minimum value of $K\ N_1/N_2$, where K is any integer between 1 and ω_1. When several choices are available, it may be desirable to select the pair having the largest value of minimum separation during motion.

The "line pins" are treated as coming into contact as they cross the center line between the two gears. Such a condition obviously would produce no stopping action on the gears, and it could result in great forces tending to separate the gears along the center line. To be effective, the point of contact of the stop pins should be somewhat removed from the center line. Probably the ideal position would be one in which the line of action of the force between the pins passed through the center of rotation of the stopping gear.

Tips and Techniques

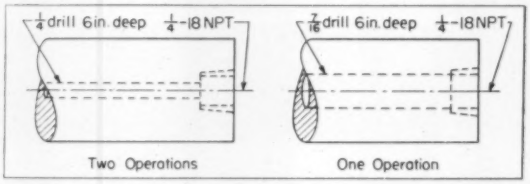
Pencil Holder

This drawing-pencil holder, cut from a piece of wood or other suitable material, is handy for use on the drawing board. It can be placed near the work, when a tray on a drafting machine may be inconvenient, enabling the draftsman to have pencils within easy reach at all times. The addition of a few slots across the top surface will provide space for keeping most-used triangles and templates.—LESTER W. GOSS, *Motorola Inc., Phoenix Research Lab., Phoenix, Ariz.*



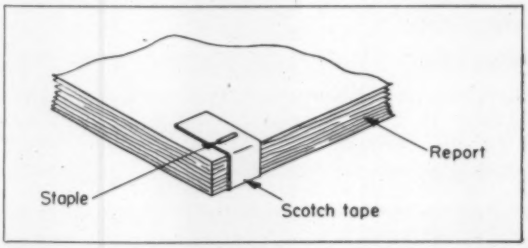
Designing Fluid Passageways

It is frequently necessary to provide a drilled hole for the passage of lubrication or other fluid. At the start of this hole, a pipe thread is tapped to receive a grease fitting or a pipe line. Often the designer makes the drilled hole equal in diameter to the pipe inside diameter or to the nominal pipe size. The hole then has to be enlarged at the entrance to tap-drill size, necessitating a second operation. With very few exceptions it is just as satisfactory and saves one operation if the tap drill is used to drill the entire passageway.—WILLIAM L. GOVAN, *Cooper Union, N. Y.*



Preventing Lost Pages

The last page or pages of stapled reports, data sheets, etc., are sometimes lost because they tear loose from the staple. This can be prevented by folding a piece of Scotch tape over the first and last pages of the report, then stapling the report together through the tape.—GIBSON A. CEDERBORG, *Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia.*



The Personal Side of Engineering

By Edwin C. Nevis

Personnel Research and Development Corp., Cleveland

What Are Engineers Made Of ?

Part 2

IN A PREVIOUS column (May 2 issue Page 109), emphasis was placed upon the perfectionism and deep sense of accomplishment that pervade the engineer's approach to his work. Briefly mentioned was the fact that engineers as a group tend to be more interested in their work and in the accomplishments they can bring about than they are in the rewards that may follow. Traditionally at least, this has been the pattern often found in the personality make-up of engineers. This pattern is breaking down somewhat, as engineers grow more conscious of their professional status. But the trend nevertheless remains one of the solid manifestations of most psychological studies of engineers.

Speaking more generally, the personality of engineers is often characterized by a matter-of-fact approach to people and life problems. As a group, engineers tend to be rather straightforward and frank. While often untrained in human relations, they nevertheless tend to deal with people in an easygoing manner, one which is neither intense nor impulsively spontaneous.

The table indicates the more frequent personality traits which occur in psychological testing of engineers.[1] It indicates frequency of occurrence of traits mentioned in psychologists' evaluation reports of 100 mechanical engineers.

Analysis of the table indicates a pattern which is, on the whole, rather typical. It points up the active, direct and conscientious nature of engineers, showing the lack of reflective and introspective tendencies. The characteristics of introversion and serious-mindedness are fairly low in occurrence. Notice, too, that sense of humor is as low as serious-mindedness, again emphasizing the unemotional, matter-of-fact outlook toward life which characterizes so many persons in the engineering field.

The implications of the pattern are many. Three in particular are quite pertinent to the performance of engineers on their jobs. First, while engineers do maintain relations with others which are not fraught with tension, their straightforward and frank manner can lead them into difficulty. Sometimes they are too blunt because they fail to give enough consideration to the subtleties of diplomacy. At other times, because of their sincerity and integrity in achieving the "right" relationship with others, they take people at face value and, hence, are surprised to find others as complex or as confusing as they often turn out to be.

Second, because engineers are not highly reflective as a group, they may lead a less rewarding life than their intellectual capacities warrant. Often, they are not too well aware of their own make-up, and do not give a great deal of attention

Personality Traits of Engineers*

Trait	Frequency of Occurrence (per cent)
Easy-going, little friction in personal relations	51
Emotionally stable	48
Active, energetic	33
Direct, straightforward	31
Conscientious	30
Frank	27
Independent, self-sufficient	27
Ambitious	26
Friendly	25
Pleasant, likable	25
Practical	24
Lack of confidence	22
"Compulsive component" (detail-minded, orderly, thorough, meticulous, perfectionistic, etc.)	22
Introverted	21
Critical	20
Dominant	20
Quiet	20
Aggressive	19
Serious-minded	19
Unaggressive	19
Diligent	18
Mild-mannered	18
Sense of humor	17
Persistent	17
Unsociable	17
Nervous, high-strung	16
Conservative	16

*Tabulated from personal evaluation reports of 100 mechanical engineers, Reference 1.

to thoughts about what they are like, what their talents are, and how they may best promote their talents.

Results of a study[2] indicate clearly that engineers tend to avoid reading periodicals and other literature which might contain high cultural value. Also, engineers do not read with great frequency what might be called low-quality magazines. However, in view of the intellectual capacity of the group, it is surprising that reading books on philosophy and politics, listening to classical music, and attending concerts are very low in frequency of recreational interest. On the other hand, sports, dancing, and the reading of fiction such as historical novels, adventure stories and mysteries are quite high. These facts suggest that engineers tend to give less consideration to their development as well-rounded persons than their basic abilities warrant.

The third implication is perhaps the most important one from the standpoint of actual job performance. This has to do with the engineer's great desire and need for self-sufficiency. As an active, frank and independent person, the engineer as a rule strives determinedly to be able to say that he stands on his own feet and achieves worthwhile results in a problem area.

This personality trait creates some difficulty in his seeking assistance when a knotty problem is encountered. As a group, engineers resist tenaciously the idea of going to peers or, particularly, to superiors for assistance when they run into trouble. Even more important, it may create a problem for engineers who are in supervisory or managerial capacities. Such men have as their main responsibility the attainment of results through others. Any supervisor who is so intent on being able to point to accomplishments attained by his own effort will probably fail to use properly the skills of others.

One further comment regarding the table seems justified. Attention has been called in a previous article to the fact that a mistaken notion exists that all engineers are orderly, meticulous and detail-minded. The table indicates the so-called compulsive component, which emphasizes orderliness, to be fairly well down on the list of traits characterizing the engineer. Thus, to invoke the stereotyped notion of the engineer as an individual hunched over his drafting board and concerned with the minutiae of technological problems would be a mistake of a gross order.

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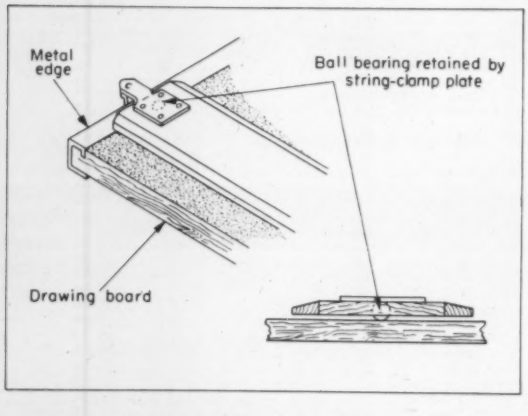
1. R. Harrison, D. Tomblen and T. Jackson—"Profile of the Mechanical Engineer, Part III, Personality," *Personnel Psychology*, Vol. 8, 1955, Pages 469-490.
2. R. Harrison, D. Tomblen and T. Jackson—"Profile of the Mechanical Engineer, Part II, Interests," *Personnel Psychology*, Vol. 8, 1955, Pages 315-330.

Tips and Techniques

Ball-Bearing Straightedge

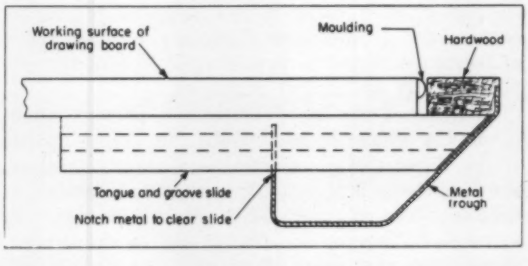
Straightedges that have string-clamp end plates and are mounted on metal-edged drawing boards may be altered to move more readily and pass over drawings on the board. Two steel balls are



secured that have a diameter about equal to the straightedge thickness plus 1/32-in. A hole is drilled at each end of the straightedge under the end plate to accommodate the balls. After inserting them in the holes, the straightedge is returned to the board.—GENE J. KRYSKO, *design engineer, research and development, Dole Valve Co., Chicago.*

Handling Large Drawings

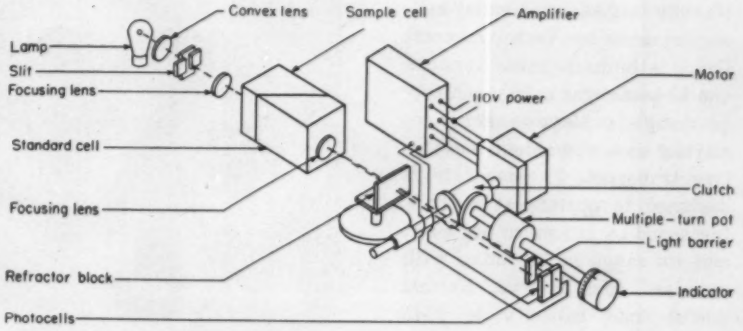
When drawing on extremely large sheets of paper or vellum, the top part of the sheet may be inconvenient to work on due to the reaching involved. Where much work of this nature is done,



a roll drawer along the front of the drafting table will be found useful. The drawer is a simple metal trough with slides at each end. The paper is rolled up, put in the trough, and as much of the paper as is needed is pulled out and fastened to the drawing board.—MARY RITCHEY, *Lockheed Aircraft Corp., Missiles Systems Div., Van Nuys, Calif.*

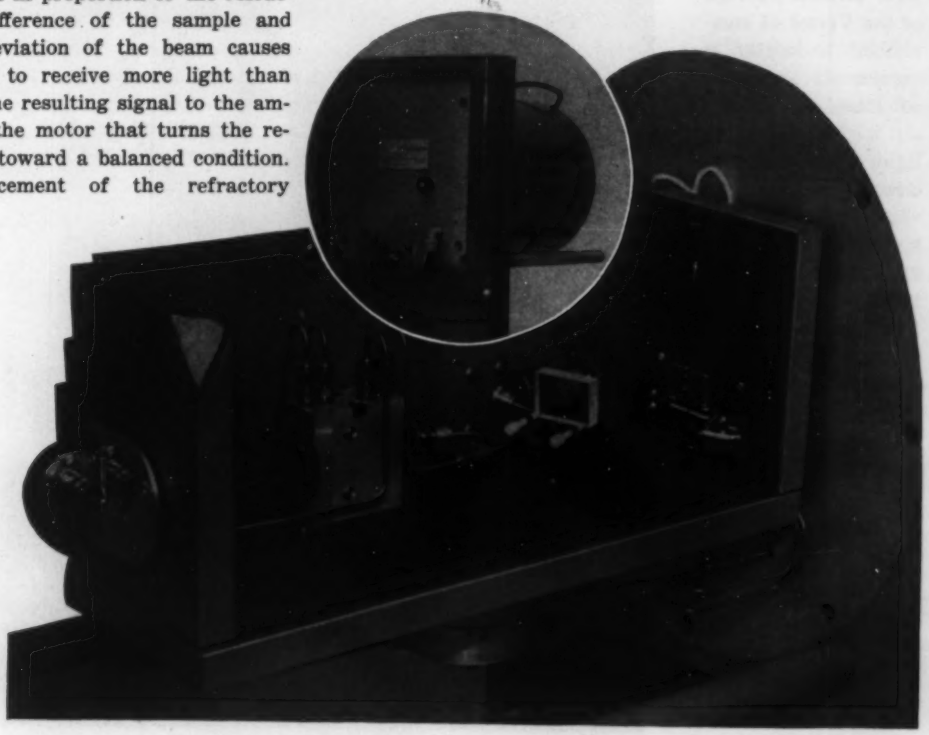
Process Refractometer Features Simplified Optical System

Continuous monitoring of the refractive index of liquid process streams is offered in a new process refractor of simplified design developed by Consolidated Electrodynamics Corp. Based on an instrument designed by the Phillips Petroleum Co., the entire electronic and optical system is housed in a pressed-steel bell to provide explosion proofing for Class 1, Group C hazardous locations.



Refractometer operation is based on measurements of the difference in refractive index between a sealed-in liquid standard and a flowing sample drawn directly from a process line. When both samples have the same index of refraction, there is no deviation of the optical system's light beam as it passes through the two liquids. Composition changes in the flowing sample deflect the beam in proportion to the refractive index difference of the sample and standard. Deviation of the beam causes one photocell to receive more light than the other. The resulting signal to the amplifier starts the motor that turns the refractor block toward a balanced condition.

The displacement of the refractory block required to achieve balance is proportional to the difference in refractive index between sample and standard. The position of the refractor block is shown on an indicating dial geared to the motor shaft. A multiple-turn potentiometer geared to the motor shaft is used in a telemetering circuit to operate a potentiometric recorder.



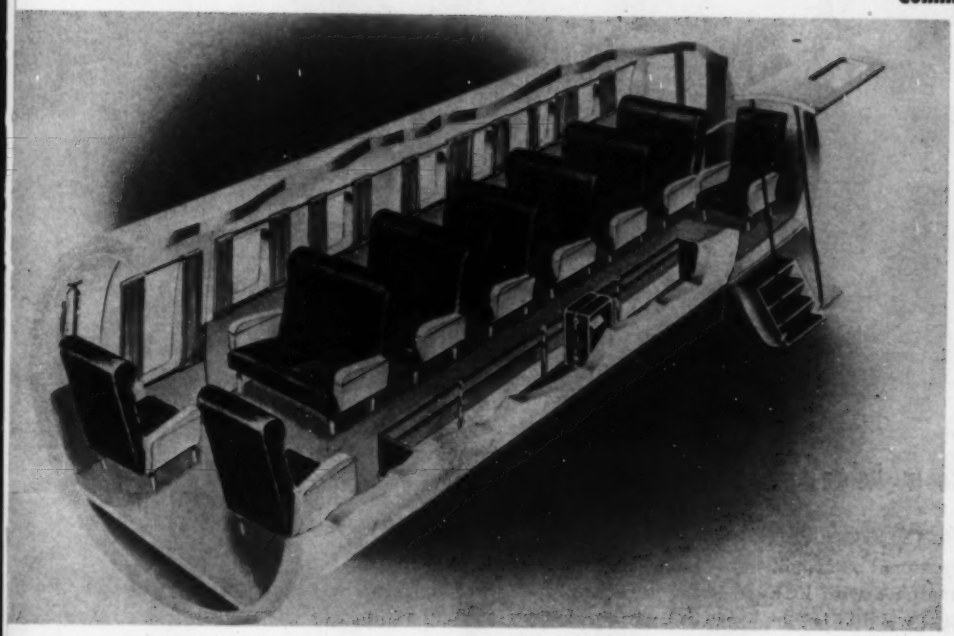
Luxury Passenger Helicopter

World's largest commercial helicopter made by Vertol Aircraft Corp. is built in three versions —a 19-passenger utility and cargo design, a 15-passenger commercial unit, and a deluxe executive transport. The machine is designed to operate at a cruising speed of 100 miles per hour, and its range is 360 miles with standard fuel reserve. Normal useful load capacity is 5345 pounds.

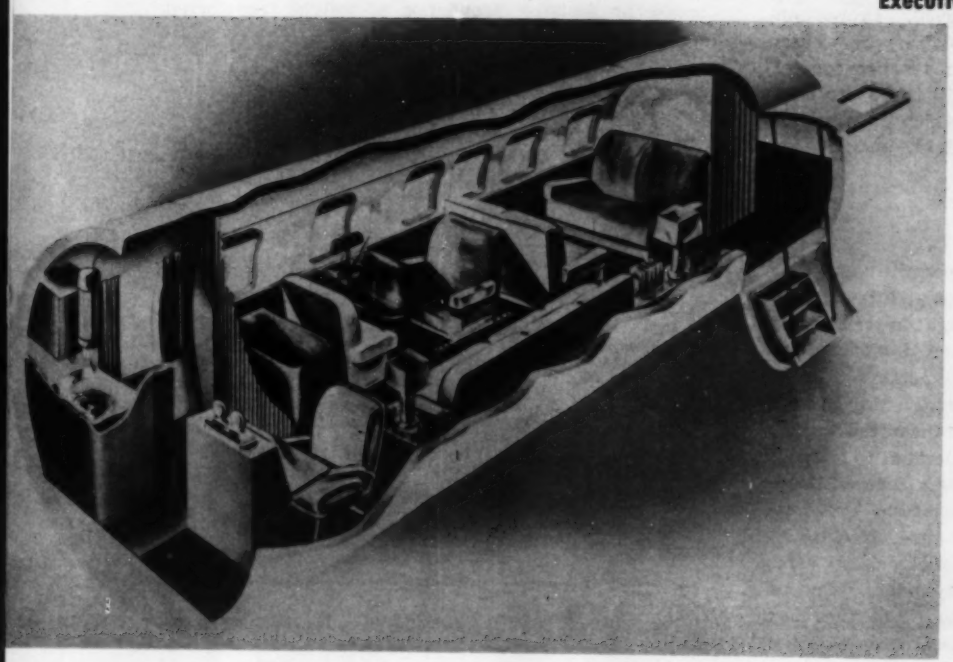
The Vertol 44's tandem-rotor design eliminates balance problems in the placement of cargo and allows passengers to sit anywhere in the cabin.

New airliner version of the Vertol 44 commercial helicopter is luxuriously appointed. Each seat has an air inlet and reading light. Large oval windows and lack of wings provide unobstructed viewing. The spacious cabin, which is 20 feet long, 5½ feet high and 5 feet, 8 inches wide, is sound-proofed throughout; the noise level is comparable to a modern fixed-wing aircraft.

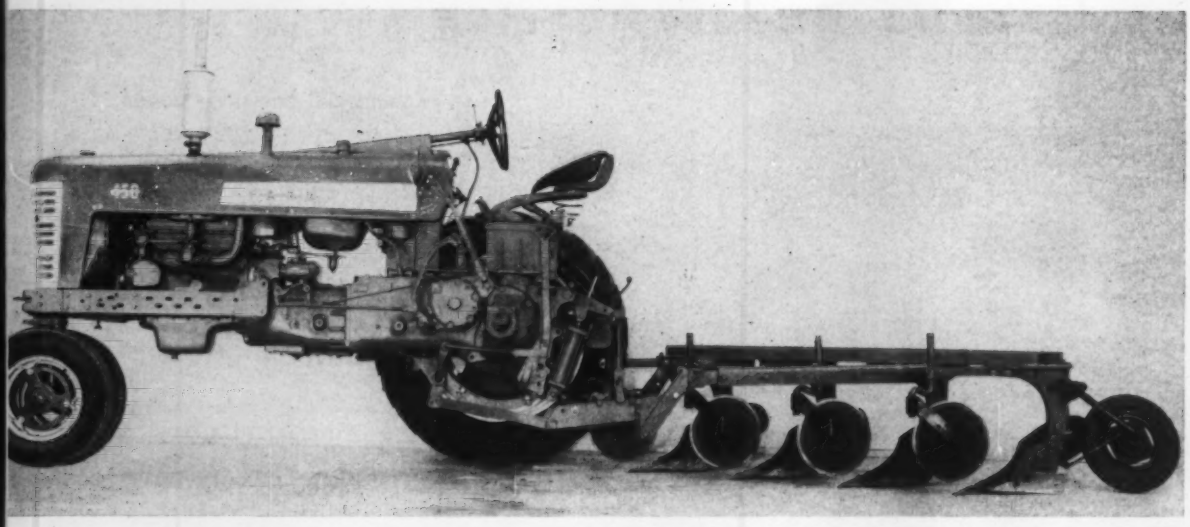
Converts to Cargo Carrier



Commercial passenger design, Model 44 B, comfortably seats 15 people. Seats in this model can be folded away or removed for rapid conversion to partial or full-cargo transport.



Executive helicopter transport, Model 44 C, features a custom-fitted deluxe interior. The main-cabin door is of clamshell design, with built - in passenger steps and handrail.



Farm Tractor Has Automatic Traction Control

Traction of new International Farmall tractors is continuously matched with load by automatically varying weight transferred to rear wheels. The design reduces slippage and need for cast-iron rear wheel weights commonly employed. Proportion of weight transferred to the rear wheels can be varied with the traction-control handle over a range of 12 to 50 per cent of the combined weight, which includes implement weight, soil weight, and tractor front-end weight.

Linkage system design permits variations in mechanical leverage to match traction to load. Implement-soil weight is transferred to tractor rear wheels as draft load increases. Arrows show directions of force as tractor pulls plow through the ground. Draft load of plow is transmitted by the draft yoke through bellcrank to pitman link which in turn applies a forward force on upper part of cam plates. The bellcrank tends to rotate forward, exerting an upward force on the rock shaft arms through the hydraulic cylinder. Upward force on lift links, attached to the rock shaft arms, causes an upward force on the hitch sockets and the plow. As a result, there is a counteracting downward pull on the tractor, which has the same effect as adding weights to the rear wheels. As traction-control handle is raised or lowered, lever arm on cam plate is lengthened or shortened to increase or decrease proportion of weight transferred.

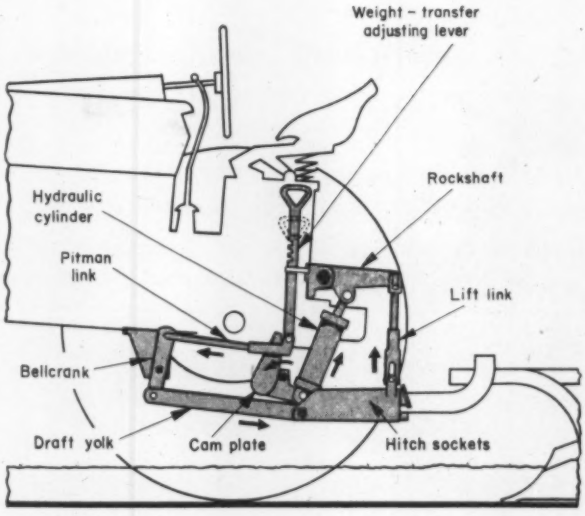


Chart gives ductile-material

ENDURANCE LIMITS

By Alex B. Carr
Lecturer in Machine Design
Ryerson Institute of Technology
Toronto, Ontario

ENDURANCE limit is commonly defined as the highest reversed stress to which a material can be subjected an infinite number of times without failing. Often in design, the repeated stress is not completely reversed, but varies from a maximum in either tension or compression to a lower value in tension or compression. The endurance limit for this type of loading is higher than that for complete stress reversal.

Experimental evidence shows that the endurance limit (or maximum design stress) for any stress variation is given approximately by

$$\frac{s_e}{s_y} = \frac{Ks_r}{\frac{s_y}{N} - s_m} \qquad (1)$$

Equation 1 can be plotted as shown in Fig. 1*a* or *b*. Fig. 2 is constructed by erecting vertical *BC* of length $CD = s_y/N$ on Fig. 1*b*. After points *A* and *B* are joined, consideration of similar triangles shows that $FG = DE = s_m$. Therefore, for any mean stress s_m,

$$EG = s_r + s_m = s_{max} \qquad (2)$$

Radial lines drawn from origin *D* of Fig. 2—say, *DG*—have slopes of value s_{max}/s_m. A line drawn at 45 deg connects points where the mean stress equals s_y/N and the varying stress is zero. This is the static-loading case where minimum load equals maximum load and ratio $s_{min}/s_{max} = 1.0$. To indicate this condition, the 45-deg ray

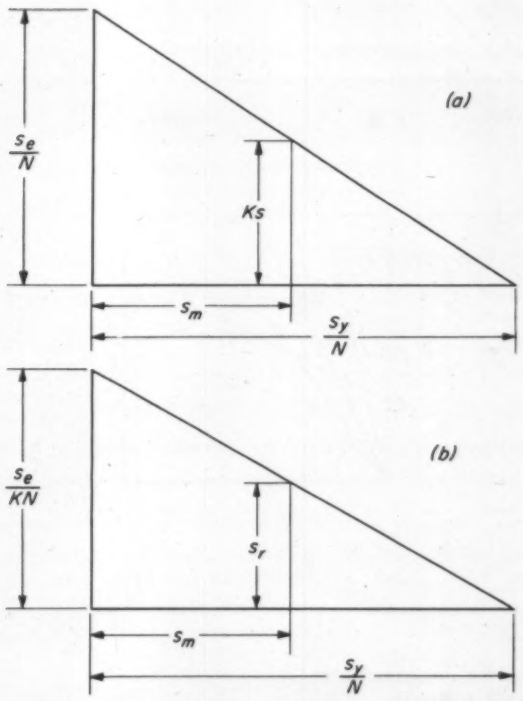


Fig. 1—Graphical representation of the effects of mean stress on endurance limit.

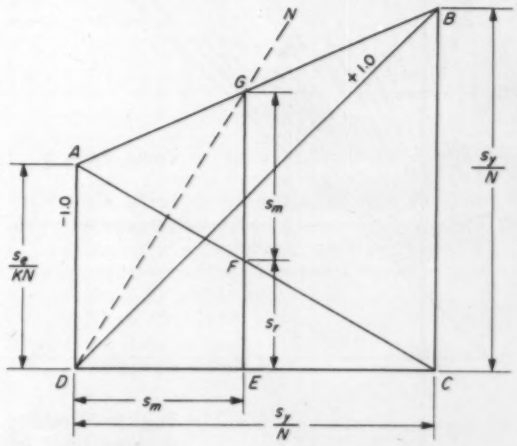


Fig. 2—Construction of endurance-limit diagram.

has been labeled 1.0.

Similarly, on the vertical ray drawn from point *D*, mean stress is zero, and varying stress (also equal to the maximum stress) is s_e/NK. In this case, minimum stress is $0 - (s_e/NK)$, and minimum stress divided by maximum stress is -1.0.

In general, rays bearing the negative sign refer to cases where minimum stress is of opposite sign from maximum stress. Where a varying stress has zero minimum (not reversed), ratio of minimum to maximum load equals zero (middle ray).

Endurance-Limit Working Chart: When ma-

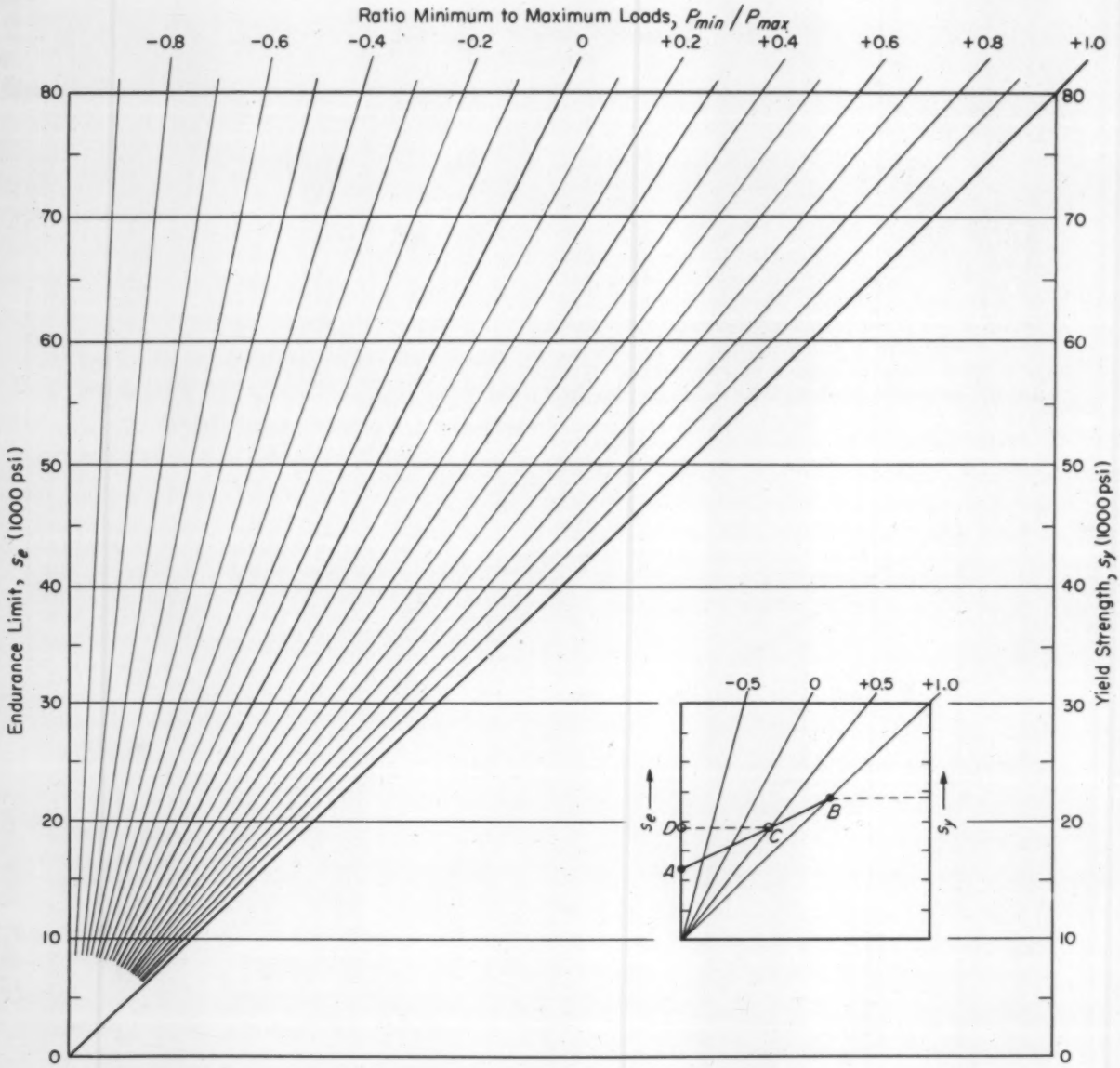


Fig. 3—Working chart for determining endurance limit for ductile materials.

chine parts are subject to uniaxial stress, such as simple tension, simple bending, or simple torsion, the required design stress may be obtained by use of a chart constructed according to the foregoing principles, Fig. 3.

Values of the endurance limit in reversed bending, s_e, are normally taken from tables of mechanical properties of materials. For steels, s_e is approximately one half of the ultimate strength in tension ($s_e = 0.5\ s_u$). This ratio is normally assumed where more precise values are not available.

Examples 1 and 2 demonstrate use of the working chart as a time-saving aid for determining maximum allowable design stress.

Example 1: A shaft is subject to a bending moment varying from 5000 lb-in. to 1000 lb-in. Ultimate stress for the material is 120,000 psi and yield stress is 90,000 psi. Stress concentration factors are: 1.6 due to a fillet radius on the shaft; 1.2 for a machined surface finish. Factor of safety is 1.5. Find the maximum design stress by direct calculation and by use of the endurance-limit working chart.

DIRECT CALCULATION: Maximum bending moment = 5000 lb-in. and minimum bending moment = 1000 lb-in. Therefore, mean bending moment = 3000 lb-in. and variable bending moment = 2000 lb-in.

Then ratio of variable bending moment to mean bending moment is

$$\frac{2000}{3000} = \frac{2}{3} \qquad \text{(E1)}$$

and this ratio must equal s_r/s_m or

$$s_r = \frac{2s_m}{3} \qquad \text{(E2)}$$

Also, as an approximation,

$$s_e = \frac{120{,}000}{2} = 60{,}000 \text{ psi} \qquad \text{(E3)}$$

Substituting these results in Equation 1,

$$\frac{60{,}000}{90{,}000} = \frac{Ks_r}{\dfrac{90{,}000}{1.5} - s_m} \qquad \text{(E4)}$$

Using the results of Equation E2,

$$5.84\ s_m = 120{,}000$$
$$s_m = 20{,}600 \text{ psi} \qquad \text{(E5)}$$

and

$$s_r = \frac{2S_m}{3} = 13{,}730 \text{ psi} \qquad \text{(E6)}$$

Therefore,

$$s_{max} = 20{,}600 + 13{,}700 = 34{,}300 \text{ psi} \qquad \text{(E7)}$$

SOLUTION BY CHART: Data required for solution by the chart method are as follows:

$$K = 1.6 \times 1.2 = 1.92$$
$$N = 1.5 \qquad \text{(E8)}$$

$$\frac{S_e}{NK} = \frac{60{,}000}{(1.92)(1.5)} = 20{,}800 \text{ psi} \qquad \text{(E9)}$$

$$\frac{s_y}{1.5} = \frac{90{,}000}{1.5} = 60{,}000 \text{ psi} \qquad \text{(E10)}$$

$$\frac{\text{min. load}}{\text{max. load}} = \frac{1000}{5000} = 0.2 \qquad \text{(E11)}$$

Locate 20,800 on the left-hand ordinate of Fig. 3 (point A on insert sketch). Locate 60,000 on 45-deg diagonal line (point B); join AB. Line AB cuts the + 0.2 ray at 34,300 psi, which is the required design stress. This stress can be used in conjunction with the maximum bending moment of 5000 lb-in. to determine shaft diameter.

Torsion: For cyclic variations of shear stress, the endurance limit for complete reversal is taken as 0.55 times the endurance limit in reversed bending, and the yield stress is 0.55 times the yield stress in tension. With these values, the stress-concentration factors and factor of safety are applied as in the case for bending, and the endurance limit obtained from the chart.

Example 2: Using the same material, stress-concentration factors and factor of safety as in Example 1, find the allowable shear stress if the shaft is subjected to a torsional moment varying from zero to 4000 lb-in.

Endurance limit in reversed shear = 0.55 × 60,000 = 33,000 psi. Also $K = 1.92$ and $N = 1.5$. Therefore,

$$\frac{s_e}{KN} = \frac{33{,}000}{(1.92)(1.5)} = 11{,}400 \text{ psi} \qquad \text{(E12)}$$

Yield stress in shear = 90,000 × 0.55 = 49,500 psi. Then

$$\frac{s_y}{N} = \frac{49{,}500}{1.5} = 33{,}000 \text{ psi} \qquad \text{(E13)}$$

and

$$\frac{\text{min. moment}}{\text{max. moment}} = \frac{0}{4000} = 0 \qquad \text{(E14)}$$

The line joining 11,400 at point A on the chart to the 33,000 value at point B cuts the ray marked 0 at 17,000 psi. This stress is used in conjunction with the maximum torsional moment 4000 lb-in. to determine the diameter of the shaft.

If it facilitates use of the chart, the factor of safety may be omitted from the original calculations. In such event, the chart value determined for maximum stress must be divided by the factor of safety to give the working stress.

Nomenclature

K = Product of all relevant stress-concentration factors due to surface condition of the material and to stress raisers such as fillets, holes, threads, etc.
N = Factor of safety (to be applied to s_e and s_y)
s_e = Endurance limit in reversed bending (mean stress is zero), psi
s_m = Mean stress, psi
= $\frac{1}{2}\ (s_{max} + s_{min})$
s_{max} = Maximum stress, psi
= $s_m + s_r$
s_{min} = Minimum stress, psi
= $s_m - s_r$
s_r = Range of stress due to variable load, psi
s_y = Yield stress, psi

Controlling electrical equipment with

Magnetic Amplifiers

By W. F. Eagan

Control Dept.
Allis-Chalmers Mfg. Co.
Milwaukee, Wis.

MAGNETIC amplifiers modulate large amounts of power in response to small control signals. Tiny outputs of photocells, thermocouples, vacuum tubes and small relays govern delivery of thousands of horsepower. Some of the quantities controlled with magnetic amplifiers are voltage, current, speed, torque, position, frequency and tension. These devices have been applied in almost every industry and now govern functions formerly controlled by rotating and electronic amplifiers and mechanical regulators. They also supplement rotating amplifiers and electronic controls, thereby extending application possibilities.

Acceptance of magnetic-amplifier regulating systems stems chiefly from their reliability, extremely fast response and high degree of accuracy. When properly applied, these units virtually eliminate maintenance problems because they contain no moving parts or electronic tubes, Fig. 1.

The following applications indicate their potential:

1. Rolling mill control for blooming mills, cold reversing mills, tandem mills, processing lines, Sendzimer mills, temper mills and table drives.
2. Voltage regulators for turbine-generators, hydrogenerators, diesel generators and special military application.
3. Miscellaneous regulators for cement kiln drives, sawmill carriage drives, mercury arc rectifiers, paper industry applications, engine starting and maintenance of jet aircraft, package drives, arc furnace control, mine hoists, and power-factor regulators.

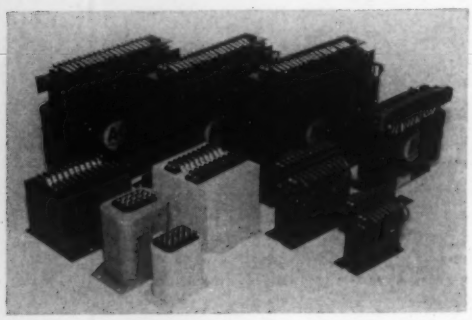


Fig. 1—Static components of magnetic-amplifier regulating systems. Rectifiers are selenium, germanium or silicon. Cores are stacked with minimum-reluctance joints.

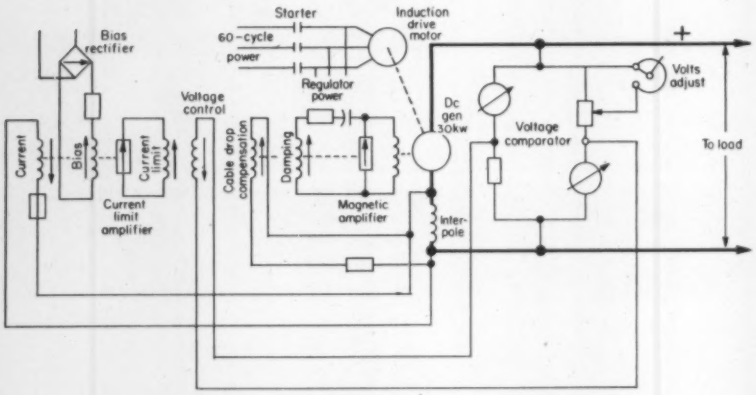


Fig. 2—Regulating system for ground power supplies. Current-limit and cable-drop compensation are included. Arrows indicate control winding polarity which increases amplifier output.

In some applications of magnetic-amplifier static regulators to small ac and dc motor-generator sets, the amplifier operates into the field of a conventional dc exciter. In other applications, it replaces the exciter, eliminating commutator and bearing maintenance. Examples of such application are two types of generator controls.

Dc Generators: In a typical control for small machines, static regulators, Fig. 2, are used with 28-v, 30-kw dc generators which supply

engine-starting power for jet aircraft. A three-phase magnetic amplifier provides field excitation for the generator-regulating system. Output voltage of the generator is sensed by a comparator made up of linear and nonlinear resistors connected in a bridge circuit.

To compensate for voltage drop in the generator output power cables, a measure of load current is introduced into a cable-drop compensation winding. As load increases, additional excitation introduced through the amplifier causes a voltage rise at the generator terminals.

Excessive overshoot of voltage during load changes is prevented by a rate-of-change signal from the generator field voltage which is fed back through a series resistor-capacitor network into a damping winding.

A second magnetic amplifier, biased well into its cutoff region, prevents excessive currents during jet-engine starting. A signal proportional to load current and in a polarity opposing the bias signal is fed into a second winding from the generator interpole. As the load current increases, the current-limit amplifier suddenly increases output with further generator loading. Current-limit amplifier and comparator outputs are opposed under this condition, and generator output is limited to maintain a safe value of current during acceleration of the starting motor. The starting motor accelerates smoothly on constant current and runs on constant voltage without contactors or relays.

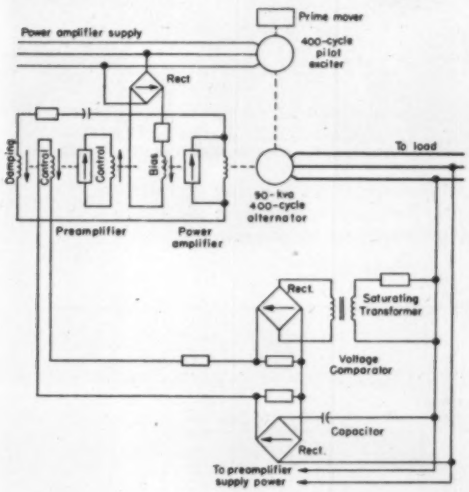


Fig. 3—Three-phase system with magnetic amplifier control rated at 90 kva, 208/120 v. Extremely fast voltage recovery results from 400-cycle power. Arrows indicate control winding polarity which increases amplifier output.

AC Generators: A magnetic-amplifier regulator for application on an engine-driven synchronous generator is shown in Fig. 3. Generator excitation comes from a three-phase power amplifier operating on ac power from a small 400-cycle pilot alternator. Bias for this amplifier drives it beyond maximum output. Preamplifier output opposes this bias. The voltage comparator for this system is a static network consisting of a saturating transformer, capacitors, resistors, and rectifiers, Fig. 3. The network has a characteristic similar to that

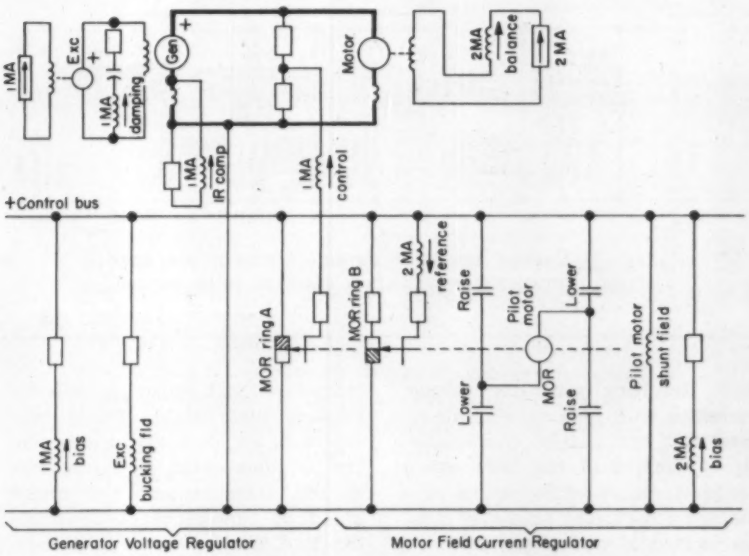


Fig. 4—Spindle speed control for one of the largest engine lathes built. Speeds from zero to maximum can be set by energizing the *MOR* pilot motor.

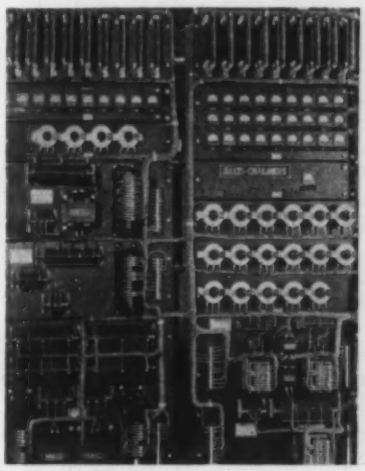


Fig. 5—Magnetic-amplifier type regulators for two-stand temper mill.

of the comparator in the dc generator system, and is virtually independent of frequency changes. Comparator output feeds a control winding in the preamplifier. System damping is by means of an RC network.

Machine Drives: Typical of the application of magnetic-amplifier regulation to machine drives is a lathe control system of three regulators: a spindle-drive generator voltage regulator, a spindle-drive motor field current regulator, and a carriage-drive motor field current regulator. Lathe spindle speed is controlled by co-ordinated operation of a generator voltage regulator and motor field current regulator, Fig. 4. The 200-hp spindle motor is supported by a dc excited generator and magnetic amplifier, 1*MA*. To prevent creeping of the spindle motor at zero speed, the amplifier is biased to cutoff and a small bucking field in the exciter cancels residual output of amplifier and exciter.

Generator voltage is set by comparing a portion of its output voltage with the set voltage on ring *A* of motor-driven rheostat, *MOR*. Any difference between the two results in a current through 1*MA* control winding which brings the voltages of generator and rheostat into balance. Drive speed is proportional to this voltage. Safe rates of acceleration or deceleration are provided by the fixed operating speed of the *MOR* pilot motor. The spindle motor accelerates to any desired speed up to that corresponding to rated voltage with full field over a portion of rheostat travel. Further travel of *MOR* results in acceleration to higher speed by weakening the field of the motor at constant armature voltage. Motor field current is regulated by amplifier 2*MA*. Reduction of field current results in further drive acceleration after rated armature voltage is reached.

A dc shunt-type motor loses speed with loading when supplied with constant armature voltage. An *IR* compensating winding provides a small amount of boosting excitation through 1*MA*, and receives a signal proportional to load current from the generator interpole. Resulting generator voltage increases with load causing an almost flat motor-speed characteristic. A portion of the lathe speed range is controlled by means of a motor field-current regulator similar to that of the spindle drive.

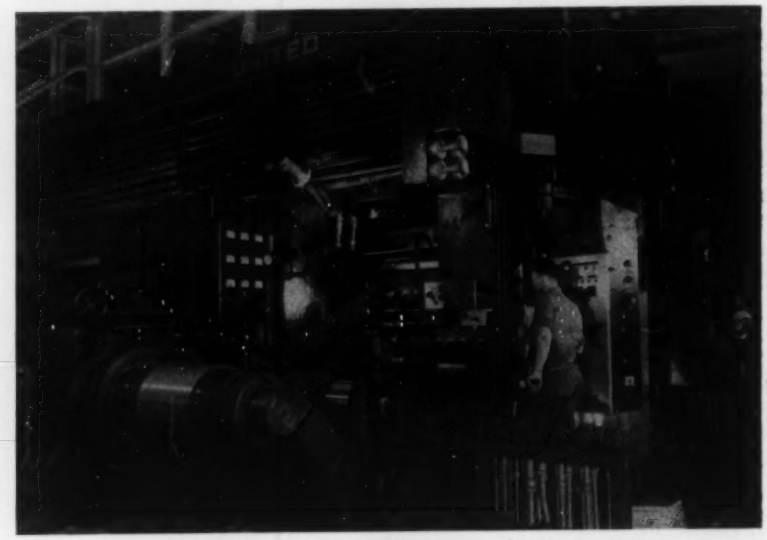


Fig. 6—Variable voltage control for winding reel drive of reversing cold mill. Reel motor armature current is regulated to a value proportional to the required value of tension.

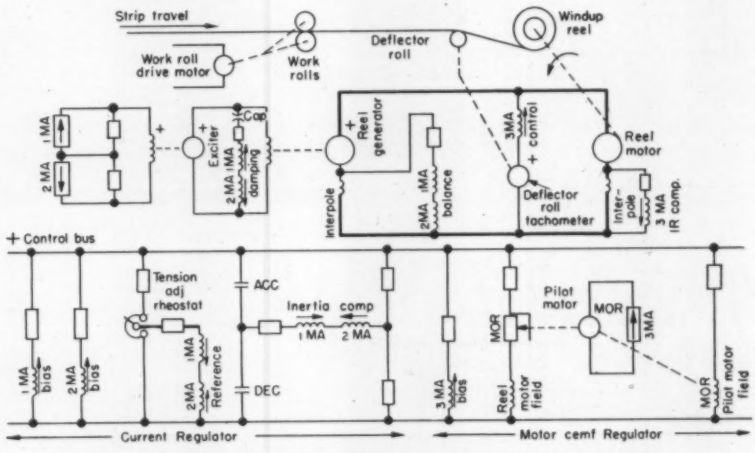


Fig. 7—Current regulator circuit of reel motor generator. Connected amplifier is used as pilot exciter.

Mill-Type Magnetic Amplifiers: Mill-type magnetic amplifiers are shown in Fig. 5. Dc variable-voltage control appears frequently in temper and cold reduction mills for winding reel drives of the type shown in Fig. 6. Strip tension control is complicated by the change in coil diameter and reel motor speed. A current regulator working into the generator field regulates armature current to a value proportional to that of the required tension. Simultaneously, a counter-emf regulator maintains internal voltage of the motor proportional

News about

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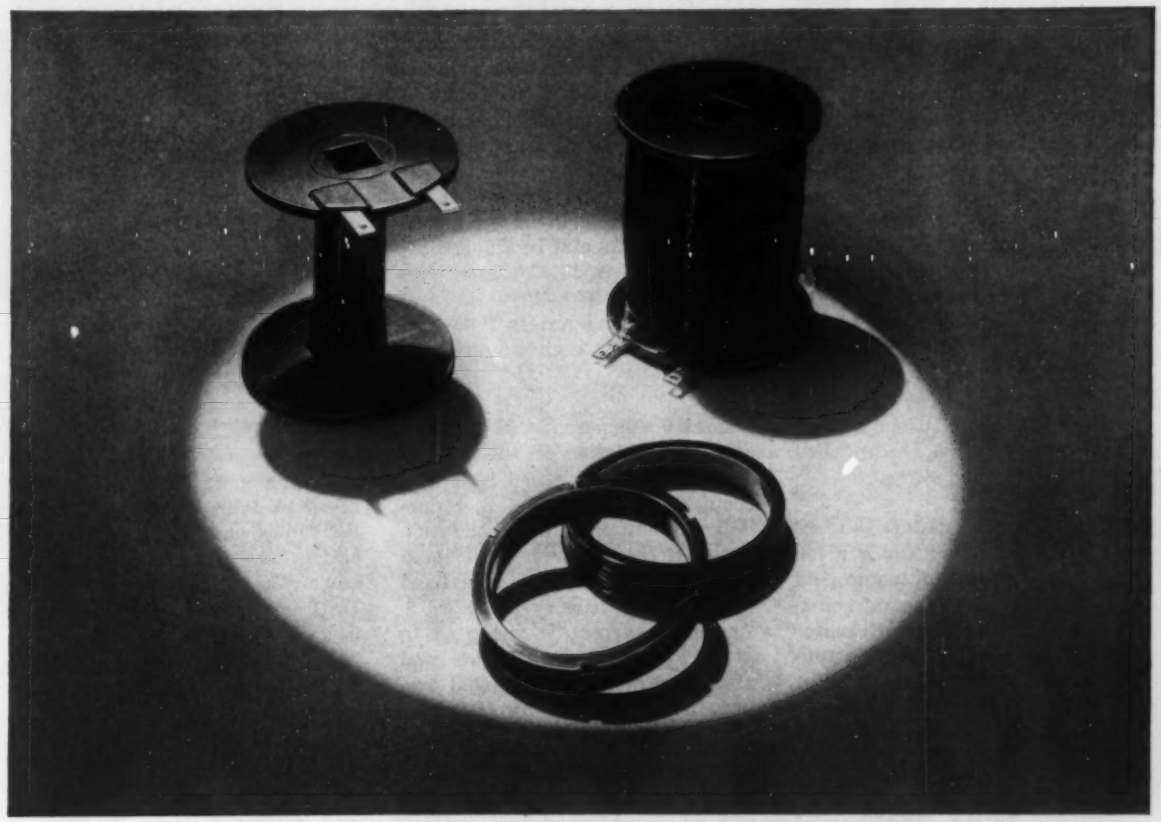

"Selected for its toughness and flexibility", *reports Stromberg-Carlson Company, a division of General Dynamics Corporation, who use the Hycar-phenolic compound for spools carrying electrical windings. In the case of the large spool, the pressure of 29,000 turns demands the toughness of this compound.*

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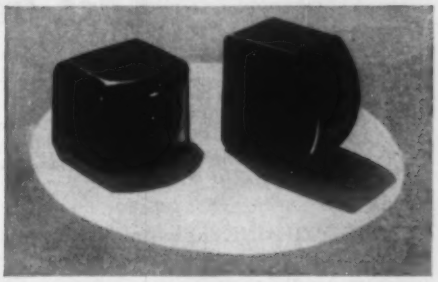

"Acoustical value important", *reports Garfield Manufacturing Company, who use the compound for relay covers. Rubber-based material deadens sound of relay operation.*

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to strip speed.

Generator Current Regulator: A magnetic amplifier supplies generator excitation through a dc exciter, Fig. 7. Both amplifiers are biased negatively to cutoff or slightly above. Ampere-turns set in reference windings tend to increase generator voltage. Armature current will increase until the ampere-turns of the balance windings almost cancel those of the reference winding. Setting the tension rheostat determines the value of armature current. Generator voltage will be maintained at a value greater than the motor counter-emf by an amount equal to the armature circuit *IR* drop. System stability and response are provided by an RC damping circuit.

Counter-Emf Regulator: Internal voltage of the motor for a given strip speed depends on motor field current to maintain constant horsepower. The rheostat pilot motor is energized by a magnetic amplifier biased to cutoff. Reel motor speed drops with coil buildup and internal voltage is reduced. When the value of motor internal voltage falls below tachometer voltage, amplifier control winding current will flow. Amplifier voltage is increased and the pilot motor advances the rheostat, increasing motor field current and counter-emf. A signal proportional to armature current from the motor interpole drop is injected into the amplifier to correct the system error caused by sensing motor-terminal voltage rather than internal voltage. Should the mill be stopped before the coil is filled, the motor-operated rheostat allows the system to hold the proper field current setting for a given coil diameter.

Inertia Compensation: Constant current regulation is satisfactory at constant mill speed, but mechanical inertia of the reel during acceleration and deceleration causes a tension error. Mill speed is set by a system giving a fixed linear acceleration rate, Fig. 8. Armature current is regulated to give required tension before and after acceleration. Additional ampere-turns provided by the *ACC* contact, Fig. 7, during acceleration result in extra torque to overcome mechanical inertia. During deceleration, the inertia-compensating ampere-turns are reversed when the *DEC* contact is closed and tension is held while the mill slows down.

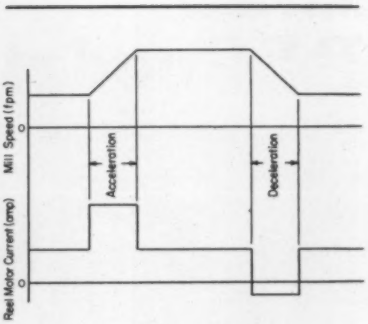

Fig. 8—Fixed linear acceleration rate. Reel-motor current is regulated to preset values during acceleration and deceleration to compensate for reel inertia.

From "Applying Magnetic Amplifiers" in Allis-Chalmers Electrical Review, *Vol.* 21, *No.* 3.

High temperature properties of *Cast Iron*

By J. R. Kattus

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Southern Research Institute
Birmingham, Ala.

TO DETERMINE the suitability of cast-iron alloys for load-carrying applications in the temperature range 700 F to 1000 F, the following seven plain and low-alloy cast irons were selected for creep-rupture tests and thermal-shock tests:

1. Molybdenum - alloyed, pearlitic gray iron.
2. Nickel - molybdenum - alloyed, pearlitic gray iron.
3. Chromium - alloyed gray iron with a matrix of 50 per cent pearlite and 50 per cent ferrite. This iron was annealed 4 hours at 1650 F.
4. Unalloyed, ferritic nodular iron.
5. Chrome-nickel-moly - vanadium-alloyed, pearlitic gray iron.
6. Unalloyed, pearlitic gray iron.
7. Chrome-moly-alloyed, pearlitic gray iron.

Creep-rupture properties of the tested cast-iron alloys are not promising for applications requiring the support of appreciable loads for long periods of time at 1000 F. The alloys with high short-time creep-rupture properties at 1000 F underwent a rapid decrease in properties with exposure times of approximately 100 to 500 hr. Alloys not experiencing this decrease had uniformly low creep-rupture properties. Cast-iron alloys are suitable for load-carrying applications at 800 F, Table 1. No rapid deterioration in creep-rupture properties occurred at this temperature in exposure times approaching 5000 hr.

Alloying has a marked effect on creep-rupture properties of cast iron. Molybdenum is the most potent alloying element for improving these properties. The chrome-moly iron had the best properties of all the alloys tested, but chromium additions alone were not beneficial. The chrome - moly iron showed properties intermediate to those of hot-rolled carbon-moly steel and hot-rolled low-carbon steel. All other irons were inferior to the low-carbon steel, although the chrome - nickel - moly-vanadium iron approached it closely. The unalloyed ferritic nodular iron was slightly superior to the unalloyed pearlitic gray iron.

Wide variations in creep-rupture properties were obtained on pearl-

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FIGURE 1 — Abrasive damage caused by pivoting arm on pill press.

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There is no practical way to eliminate abrasion on most applications. It occurs wherever there is friction between two materials.

There is, however, a simple way to slow down its ravages: "Wearproof" critical machine and product parts with harder, smoother materials.

The hardest materials designers have available are cemented carbides. Carboloy cemented carbides range up to 93 on the Rockwell "A" scale . . . compared to only 84 for SAE 1095 heat-treated carbon steel. Carbides can outwear steel by 10, 50, or as much as 100 to 1.

As for smoothness, cemented carbides take so fine a finish they are in widespread use as gage-blocks accurate to millionths of an inch.

FIGURE 2 — Gage blocks made of cemented carbide. Surface finish of .0005".

This combination of extreme hardness and smoothness has lead to thousands of applications for cemented carbides throughout industry.

For example, nozzles handling abrasive liquids from centrifuges at 1200 psi (Figure 3) are made entirely of Carboloy cemented carbide. The carbide provides a service life of 8 to 12 months — twice that of the rubber-lined nozzles previously used.

FIGURE 3 — Carbide nozzles on Merco Centrifugal Co. equipment withstand separating forces 9000 times that of gravity.

In the textile industry, carbide guides for high-speed braiders (Figure 4) wear as long as 6 years — compared to an average of 2-3 weeks for conventional hardened steel. The carbide provides more uniform finish, and easily resists the abrasive synthetic fibers.

FIGURE 4 — Carbide stop eyes for high-speed Mossberg braider.

In subsurface pumps for oil wells, Carboloy cemented carbide balls and seats (Figure 5) resist acids and abrasive sands. They outlast steel up to 20 times, and the balls maintain sphericity under the severest conditions of impact and pressure.

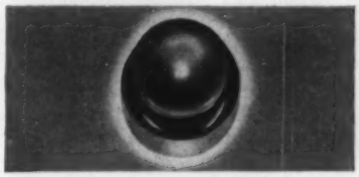


FIGURE 5 — Carbide balls and seats for oil-well pumps.

For power socket wrenches, sockets equipped with Carboloy cemented carbide inserts (Figure 6) outlast ordinary materials 15 to 20 times. The carbide stops product damage from slippage, cuts socket replacement costs.

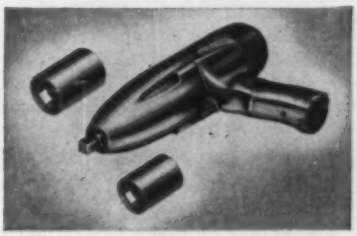


FIGURE 6 — R. J. Williams power socket wrench uses carbide inserts in sockets.

From the designer's viewpoint, one of the major advantages of carbides is their versatility.

Carbides can be produced in a broad assortment of sizes and shapes — hence there is almost no limit to their design possibilities. And they are available in a wide range of grades — hence almost any combination of physical properties can be produced.

Carbides have high compressive strength—1 to 6 times that of steel. They have tremendous resistance to twisting and deformation under load — 2½ to 3 times that of steel.

These and other unique physical properties are the reasons that carbides are now in use throughout industry, protecting valuable equipment from premature scrapping due to wear. If you have a wear problem—whether abrasion, erosion, friction, or corrosion — carbides may well be the answer.

For design assistance, or technical data on Carboloy cemented carbides, write: *Metallurgical Products Department of General Electric Company, 11126 E. 8 Mile Blvd., Detroit 32, Michigan.*

Progress Is Our Most Important Product

GENERAL ELECTRIC

Carboloy is a trademark of General Electric Company

Circle 440 on page 19

itic gray irons with similar matrix and graphite structures. Partial spheroidization of carbide occurred after about 100 or more hours exposure at 1000 F. This structural change correlated with the rapid deterioration in creep-rupture properties. The structures of annealed chromium-alloyed iron and ferritic nodular iron did not change during tests at 1000 F, and showed no rapid deterioration in their creep-rupture properties. Creep-rupture properties of annealed samples of relatively strong chrome-moly gray iron underwent rapid deterioration after about 100 hr at 1000 F, although no structural changes could be detected after the tests. No structural changes were detected in any of the alloys in tests up to 5000 hr at 800 F.

Suitability of cast iron for many applications depends upon its ability to withstand thermal shock. Efforts were made to determine the characteristics of cast iron under severe thermal-shock conditions. Since creep-rupture tests indicated that cast-iron alloys are not promising for service at 1000 F, thermal-shock testing was carried out at 800 F. Test specimens were thermally cycled between 800 and 150 F while subjected to external bending loads. Heating time in each thermal cycle was 85 sec and cooling time, 15 sec. Smooth and notched specimens were tested. Smooth nodular-iron specimens never ruptured in thermal shock.

Each alloy was tested at a number of stress levels. A thermal-fatigue endurance limit was invariably approached within 100 cycles on thermal-fatigue curves. Below the stress level corresponding to this number of cycles, thermal-shock failures are not likely to occur under the conditions of the test regardless of the number of cycles.

Table 1 compares the 10-year rupture strength and thermal-fatigue endurance limit for various alloys at 800 F. The 10-year rupture strength is based upon an extrapolation of the test data and also upon an approximation afforded by Larson-Miller parameters.

Stresses shown are recommended as the maximum applied tensile stresses for the various alloys in applications involving creep or thermal shock. Thermal-fatigue endurance limits are not absolute values but depend upon conditions of test. Values given apply to repeated severe applications of thermal shock equivalent to that produced in tests on notched specimens. Maximum stresses for service applications involving both creep and thermal shock should be based upon the 10-year rupture strength or thermal-fatigue endurance limit—whichever is lower.

Unalloyed ferritic nodular iron was far superior in thermal-shock resistance to any of the gray irons tested. Small additions of molybdenum and nickel improved thermal-shock resistance of gray iron.

From a progress report on a research project on "Properties of Cast Iron at Elevated Temperatures" sponsored by the ASTM-ASME Joint Committee on the Effect of Temperature on the Properties of Metals, January, 1957.

Table 1—Physical Properties of Iron Alloys at 800 F

Alloy	10-Year Rupture Strength (psi)	Thermal-Fatigue Endurance Limit in Tension (psi)
Chrome-moly gray iron	30,000	17,500
Molybdenum gray iron	25,000	15,000
Chrome-nickel-moly-vanadium gray iron	25,000	16,000
Unalloyed ferritic nodular iron	17,000	27,500
Unalloyed gray iron	15,000	12,500
Nickel-moly gray iron	25,000	18,000
Chromium gray iron	.....	12,500

Designing Efficient Controls

By Ralph J. Meyer

Collins Radio Co.
Cedar Rapids, Iowa

THE TASK of developing improved electronic controls to reduce operator error and improve operation may be accomplished through application of the following design criteria:

1. Horizontal digital type counter presentations of all frequency and/or channel indications.
2. Left-to-right reading of counters.
3. Simple design of numerals and/or letters.
4. Large, easily read, ¼-in. high numerals and/or letters.
5. Reduced eye movement necessary to obtain the desired information.
6. Counters mounted close to panel so that numbers are not obscured by panel opening.
7. Adequate illumination.
8. Shape, size and location of each control knob selected to accomplish the desired action with a minimum chance of error.
9. Operation of all control knobs under severe environmental conditions.
10. Sharp, crisp detent action on all applicable controls to give positive indication and permit "counting" type operation.
11. Simple nomenclature and compromise on location of controls to give optimum visual and operational characteristics.
12. Simplification of operational requirements where possible to reduce panel area.

In situations where there are many types of electronic equipment, it is often desirable to integrate several control panels into one. This allows regrouping of all controls in logical order and results in improved presentation and operation of all control functions.

From a paper entitled "The New Look In Electronic Controls" presented at the IRE National Convention in New York, March, 1957.

Experimental block being readied for torture test on Johns-Manville's Inertia Dynamometer—the world's largest unit designed for friction material testing.

Man in charge of putting more mileage into J-M Brake Blocks

Creating new and better brake blocks is a never-ending responsibility of J-M engineers. Working with the very latest in scientific development equipment, these men are blazing new trails in improved friction material performance.

Over the years, Johns-Manville has offered a wide choice of thoroughly proved, high-quality, high-performance brake linings, brake blocks and clutch facings. This superiority stems from engineering and production techniques that assure uniformly highest quality. These techniques also provide volume production, rapid delivery and lowest unit cost.

Chances are a J-M material incorporating all the properties you need for your friction applications is already available. If not, let us help you find the solution. The Johns-Manville engineering staff, a superbly equipped development laboratory, and skill gained through 99 years of manufacturing experience, are at your service.

Your Johns-Manville Representative will gladly tell you more about this service, or write to Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.

JOHNS-MANVILLE JM PRODUCTS

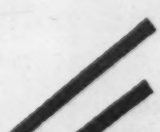
Johns-Manville

Molded and Woven Brake Linings

Molded and Woven Clutch Facings

Molded Brake Blocks

Molded Segments for Automatic Transmissions



Woven Transmission Band Linings

Circle 441 on page 19

Helpful Literature
for Design Executives

For copies of any literature listed, circle Item Number on Yellow Card—page 19

Generators

How Leland 300 to 3000-w generators are built is shown in bulletin 700 with tabulated ratings and approximate dimensions. Quill and two-bearing generators and motor generator sets are used for supplemental or emergency power. 8 pages. Leland Electric Co.

Circle 501 on page 19

Practical Plastics

"How the Nosco Plant Works" is title of brochure which pictures a variety of plastic products made by this company. These cover large molded housings to small motor parts, pipe fittings, packages and containers. 12 pages. Nosco Plastics, Inc.

Circle 502 on page 19

Portable Tool Motor Parts

General and performance data, ratings and applications of series wound universal motor parts, polyphase high-cycle parts and induction type Uni-verters are content of illustrated brochure 455-A. Specifications of all units are presented. 16 pages. Robbins & Myers, Inc.

Circle 503 on page 19

Color TV Masks

Principal steps in manufacturing aperture masks for color television picture tubes are described and illustrated in Data Memorandum No. 5. Each mask has about 500,000 tapered holes etched into it. Applications of the photoetching process are covered. 4 pages. Superior Tube Co.

Circle 504 on page 19

Spaghetti Tubing

Dielectric, handling and performance data on Polypenco Teflon spaghetti tubing are listed along with applications in data sheet BR-4A. Electrical and physical property data are given. Offered are 26 sizes, 10 colors. 2 pages. Polymer Corp. of Pennsylvania.

Circle 505 on page 19

Switches

Illustrations of extensive line of precision switches for electronic control requirements are found in bulletin 84-241. Included are basic, rotary selector, pushbutton, toggle and door interlock types. 4 pages. Minneapolis-Honeywell Regulator Co., Micro Switch Div.

Circle 506 on page 19

Hydraulic Power Units

Oil-Dyne hydraulic power units described in illustrated databook include pumps, cylinders, valves, pressure switches and accessories for pressures ranging up to 3000 psi. Complete packaged units as well as components are covered. 52 pages. Oil-Dyne Inc.

Circle 507 on page 19

Carbon & Alloy Steels

Six "Steel Casting Specifications" bulletins give complete information on low, medium, medium high and high carbon steel as well as on T-Loy 34 and 42 alloys. 4 pages each. Unitcast Corp.

Circle 508 on page 19

Pull-Type Rivets

Commercial Lockbolts are designed to replace hot or cold driven conventional rivets, bolts, welds and other fasteners. They are available in 3/16 to ½-in. diameters with brazier or countersunk heads. Complete information is given in bulletin TL-101. 8 pages. Townsend Co.

Circle 509 on page 19

Sintered Powdered Metals

Entitled "An Engineering Handbook on Powder Metallurgy", technical bulletin No. 1 gives design and application data on bushings, bearings and special parts made of cast bronze and powdered metal. Specs, properties, size ranges and typical parts are presented. 24 pages. Bunting Brass & Bronze Co.

Circle 510 on page 19

Brakemotor

Torque ratings from 3 to 345 lb-ft are available in line of Reliance Brakemotors described in bulletin B-2503. They are available in all types of enclosures for practically any operating condition. 2 pages. Reliance Electric & Engineering Co.

Circle 511 on page 19

Carbon-Graphite Products

Forms 1164 and 1174 deal with electro-mechanical, thermal and physical properties of Karak carbon graphite which is made in various compositions for use as bearings, seals, contacts, molds and many other parts. 4 and 2 pages. Ohio Carbon Co.

Circle 512 on page 19

Air Filter Panel

Available sizes and performance data on P-70 Air-Maze washable, dry type, air filter panels are given in bulletin P70P. Filters are made up of polystyrene bonded glass fiber media, aluminum lint screen and galvanized steel channel. 2 pages. Air-Maze Corp.

Circle 513 on page 19

Torque Converters

Torque converters and their applications are subject of bulletin 468. Included is capacity chart covering input speeds of 700 to 2500 rpm and output from 50 to 1000 hp. Development, design, types, sizes and circuits are discussed. 6 pages. National Supply Co., Industrial Products Div.

Circle 514 on page 19

Flexible Couplings

Series D100 Dihedral flexible couplings in standard, mill motor and floating shaft types which handle shaft misalignment up to 12 degrees are detailed in catalog 62. Capacities range up to 965 hp at 100 rpm. 8 pages. Ajax Flexible Coupling Co.

Circle 515 on page 19

Welded Design

"Elements of WELDesign" is a series of guide booklets which deals with economies to be effected through use of welded fabrication of machine and equipment components. Techniques, design considerations and actual case studies are cited. 4 pages each. Lincoln Electric Co.

Circle 516 on page 19

Washers & Stampings

Illustrated catalog No. 40 contains complete information on line of washers and stampings. Described are such items as expansion plugs, spring tension washers, odd-shaped

(Advertisement)

How engineers eliminate costly manufacturing headache by

Adding One Specification to Prints

Cut Production Costs While Improving Design

DESIGN and process engineers are now helping to get rid of one of the costliest headaches in almost every metalworking plant—the removal of burrs from machined parts. Such burr-removal often costs more than the original machining itself.

You too can do this for your parts—just by adding one dimensional specification that will cut costs and improve your product.

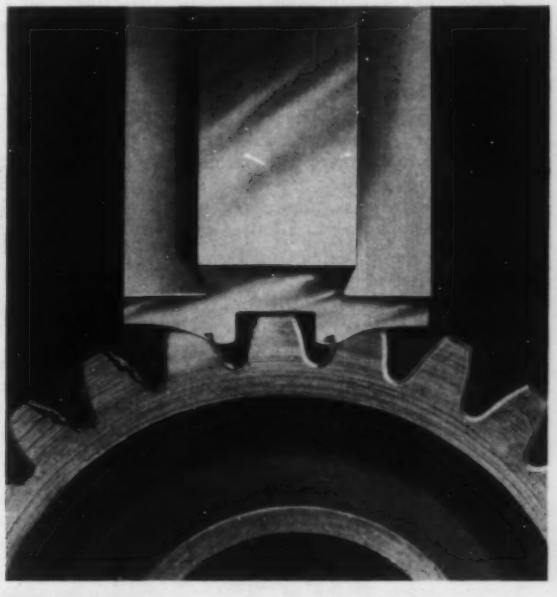
How?

Simply by specifying dimensional generated chamfers on parts prints. Specify them for those part edges on which burrs are normally left by machining. Such generated deburr-chamfers can now be accurately produced on MODERN Burr-Masters at amazingly low cost and high speeds. Symmetrical toothed elements, including internal and external gears, can be chamfer-deburred over the entire tooth contour—flank, tip, root and fillets—at an average speed of *five teeth per second!*

Note how the MODERN Burr-Master produces a generated chamfer that both positively removes the burrs and provides a functional chamfer of any reasonable width desired on the part.

There are many types of MODERN Burr-Masters to take care of different kinds of parts. They can even get into the most surprisingly inaccessible places to chamfer-deburr. Chances are we have just the Burr-Master to suit your needs.

Our engineering department will be happy to provide you with complete details. Therefore may we suggest you send them prints of some of your parts that now have to be deburred. If possible, include sample parts, with the burrs still on them.



14230 BIRWOOD AVE. **MODERN®** DETROIT 38, MICHIGAN
Industrial Engineering Co.

washers and standard types. Technical data are included on wire gages; U.S. Standard threads, bolts and nuts; and circumferences and areas of circles. 20 pages. Wrought Washer Mfg. Co.

Circle 517 on page 19

Special Steels

Stainless steel, electrical materials, Carmet carbide materials and tool steels are tabulated as to properties, analyses and applications in illustrated design manual "Special Steels for Industry." 16 pages. Allegheny Ludlum Steel Corp.

Circle 518 on page 19

Aluminum Aircraft Castings

High strength Ductaluminum 356 castings for aircraft structural members are described in bulletin H-113. Typical parts made of 38,000 and 42,000 psi tensile strength materials are shown. 6 pages. American Brake Shoe Co.

Circle 519 on page 19

Optical Tooling

Such standard items as jig transits, alignment telescopes and tilting levels as well as instrument stands, fixtures, collimators, scales, targets and optical attachments are included in the line of optical tooling equipment described in illustrated catalog. 20 pages. Keuffel & Esser Co.

Circle 520 on page 19

Special Transformers

High power pulse, hermetically sealed military, subminiature binary and toroid transformers are among the line of military and special commercial transformers described in bulletin TR500. 4 pages. Laboratory for Electronics, Inc.

Circle 521 on page 19

Piezoelectric Transducers

General applications of piezoelectric transducers as accelerometers; pressure, force and high temperature pickups; and output standardizers are discussed in illustrated bulletin. Charts and tables supplement the design information. 16 pages. Endevco Corp.

Circle 522 on page 19

Wire Rope Assemblies

Various combinations of Tru-Loc fittings and assemblies with wire rope for use as anchor cables, bridge railings, conveyor parts, safety belts, rigging and hundreds of other uses are desecribed in catalog TL 500. Data are given on special wire rope assemblies, made to customer specification. 24 pages. American Chain & Cable Co., Wire Rope Div.

Circle 523 on page 19

Liquid Chemical Filter

Technical data on use of honeycomb filter tubes for micronic clarification of liquid chemicals at various temperatures are found in bulletin AFD50-1B. They are made of various natural and synthetic fibers. Resistance to 120 chemicals is given. 6 pages. Commercial Filters Corp.

Circle 524 on page 19

Small Tubular Metal Parts

Facilities and services for the design, tooling and fabrication of precision tubular parts and subassemblies are covered in bulletin 2056. Tubing size range in components is from 0.01 to ⅝-in. diameters. Typical parts produced to users' specifications are shown. 4 pages. H & H Machine Co.

Circle 525 on page 19

Cable Sleeves & Adapters

Extension and adapter sleeves for multicircuit cables, described and illustrated in bulletin 257, provide a good electrical circuit and a strong mechanical connection of connector to cable. Various types available are described and a selection chart is included. 4 pages. Pacific Automation Products, Inc.

Circle 526 on page 19

Fans

Resin-bonded glass fiber fans described in illustrated bulletin FI-511 resist an extensive group of listed acids, alkalies, salts, gases and organic materials. Inlet sizes range from 6 to 32 in. and capacities up to 34,000 cfm. 4 pages. Buffalo Forge Co.

Circle 527 on page 19

Laminated Pipe

Design, construction and applications of Fluoroflex-T pipe, a chemically inert, fractureproof pipe made from Teflon resin and glass fiber, are outlined in bulletin FTL-2. Drawings and specifications show how it can be used in existing piping systems. 4 pages. Resistoflex Corp.

Circle 528 on page 19

Electrical Connectors

Pyle-Star line of compact, lightweight electrical connectors meet and exceed military and NEMA requirements for power, light, control and coaxial circuits. Plugs and receptacles are impervious to water, oil, gas, dust, pressure, vibration and shock. They are described in illustrated bulletin 637. 4 pages. Pyle-National Co.

Circle 529 on page 19

Valves

Electro-Pact and hand lever operated ¼-in. four-way, five-port Quick-Dump valves are for use on gases or fluids. Each type is described, and their specifications given in data sheet. 2 pages. General Gas Light Co., Humphrey Products Div.

Circle 530 on page 19

AC Motors

Performance curves for 1 and 1½-in. blowers, plus engineering data, are contained in bulletin on 900 frame alternating current motors. They can be supplied as servo, fan or blower motors. 1 page. Induction Motors Corp.

Circle 531 on page 19

Curtain Wall Sealer

Weatherban polysulphide-rubber base sealers for curtain wall use are subject of illustrated folder Z-CWS. Eleven case histories cover uses in diversified industries. Physical properties and performance data are given. 4 pages. Minnesota Mining & Mfg. Co., Adhesives & Coatings Div.

Circle 532 on page 19

Threaded Fastener Sealant

Desired locking torque can be obtained on nuts, bolts, screws or other threaded fasteners with Loctite sealant, described in illustrated bulletin. It renders them vibration resistant and fluid-tight, yet permits disassembly without breaking. 4 pages. American Sealants Co.

Circle 533 on page 19

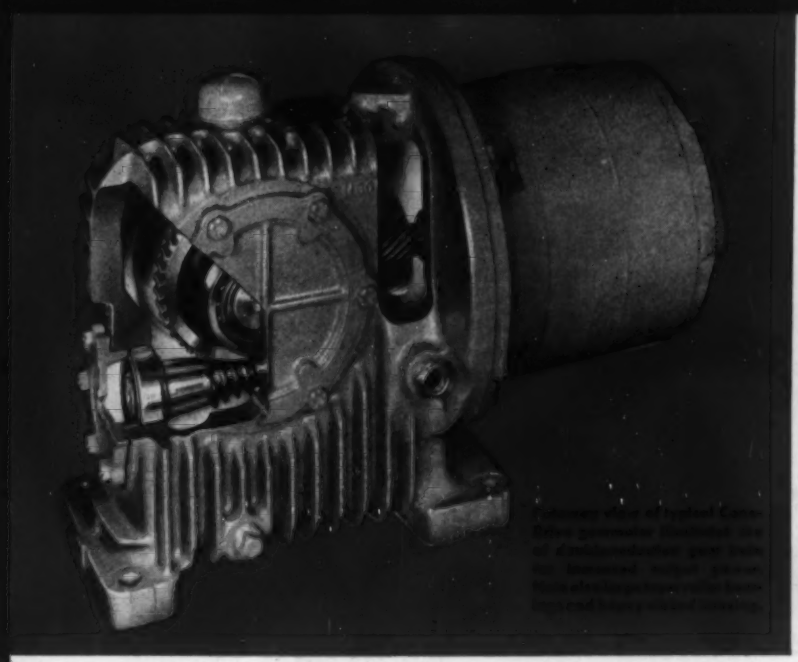
Square Cylinders

Logansquare cylinders for air or oil service conform to JIC standards, according to 16-page illustrated catalog 100, section 5. They are built in 14 mounting styles with 1½ to 8-in. bores. Operating pressures are 150 psi for air and 300 psi for oil. 16 pages. Logansport Machine Co.

Circle 534 on page 19

Rubber Shapes

Specifications and general data on an extensive line of molded and extruded rubber products are contained in illustrated engineering catalog 100. Rubbers of various types with varying hardness and tensile strength are used. Special requirements can be



Announcing a

POWERFUL NEW DRIVE

by

CONE-DRIVE GEARS

Here are the "why's" for this new gearmotor

Why a right-angle gearmotor?
You save space! By tucking the entire unit in close to the driven shaft, there's nothing to stick out in crowded aisles. It's out of the way.

Why a double-reduction design?
More power! Combining a helical primary with a Cone-Drive double-enveloping worm gear secondary gives you an extremely high load-carrying capacity. Output torque ratings are much higher than those of single reduction gearmotors. Overall ratios are greater, too.

Why double-enveloping worm gears?
More power! Cone-Drive double-enveloping worm gears have proven that they provide maximum load carrying capacity on extremely small center distances. This means, in many cases, that they will handle two to four times the load of cylindrical worm gears of the same size. An added plus is high resistance to shock loads, long operating life and minimum maintenance requirements.

Why different types of mountings?
Flexibility! You can select Cone-Drive gearmotors with extended shaft or for shaft mounting. Both are standard. Shaft mounting often permits "hanging" the driven load on the gearmotor to eliminate pillow blocks, bearings, torque arms, shafts, pulleys, bed plates, etc. Both types may be floor, wall or ceiling mounted as desired.

Why 27 standard output speeds?
Standardization! Standard reductions range from 3.3:1 to 240:1. Speeds at 1750 rpm input range from 525 rpm to 7.3 rpm output speed. Any variation in input speed will naturally provide another complete set of 27 output speeds. Any standard type NEMA D-flange motor may be used. Other reductions may be obtained on special order at additional cost.

Why ratings to only 25 horsepower?
Demand! Extensive market research by Cone-Drive Gears reveals that this is the most popular power range in the application of gearmotors by industry. Currently we are building models in capacities from 1 to 25 horsepower. However the compact size and high capacity of the Cone-Drive gearmotor will extend this range in the future. Space requirements for higher capacities will be substantially reduced with our new design.

Why a Cone-Drive gearmotor?
Dependability! For over 20 years Cone-Drive Gears has been building double-enveloping worm gears and speed reducers. Design and manufacturing techniques have been constantly improved so that today these unique gears provide, size for size, the highest load-carrying capacity of any right angle worm gearing. Now, you can take advantage of this outstanding gearing combined into an integral package that eliminates pulleys, sheaves, belts, chain, bearings and all the trouble that goes with separate reducer and motor combinations. You'll get increased efficiency at lower cost by specifying standard Cone-Drive gearmotors.

Bulletin #57 contains complete details. Ask for it today.

◀ **Here's the finest shaft mounted gearmotor on the market today. It is available in all sizes with ratings identical to other Cone-Drive gearmotors.**

CONE-DRIVE GEARS
Division Michigan Tool Company
DOUBLE ENVELOPING GEAR SETS & SPEED REDUCERS
7171 E. McNICHOLS ROAD • DETROIT 12, MICHIGAN

Circle 443 on page 19

met. 8 pages. Continental Rubber Works.

Circle 535 on page 19

Polystyrenes

General data, properties, design considerations, fabricating techniques, finishing operations and applications for various types of conventional and modified polystyrene are presented in detailed technical bulletin C-6-231. 24 pages. Koppers Co., Chemical Div.

Circle 536 on page 19

Worm Gear Drives

Facts on worm gear drives and their application to mechanical power transmission are found in illustrated bulletin 145. Standard line of speed reducers, worm gear sets and special units is covered. 16 pages. Cleveland Worm & Gear Co.

Circle 537 on page 19

Guide to Filters

Disposable media gravity, combination gravity and magnetic, straight magnetic, vacuum, pressure and screen type settling filters are illustrated in descriptive brochure. Operation and applications of each are covered. 8 pages. Industrial Filtration Co.

Circle 538 on page 19

Counting Circuits

Technical data on plug-in and permanently installed types of transistorized counting circuits are given in catalog 11437. Design, construction and application details are presented. 4 pages. Walkirt Co.

Circle 539 on page 19

Hydraulic Cylinders

Detailed information on construction and features of 2000-psi hydraulic cylinders, including trunnion mounting types, are found in illustrated bulletin 57-68. Tables of sizes and engineering data on application, mounting, piston areas, speeds, etc., are included. 10 pages. Vickers Inc.

Circle 540 on page 19

Time Delay Relays

Construction details on three basic time delay relays in new extruded hermetic housings are contained in bulletin AWH TD406. Delays from 1½ seconds to 90 minutes are available. 2 pages. A. W. Haydon Co.

Circle 541 on page 19

Titanium Pipe & Tubing

Technical data folder TDC-185 discusses seamless titanium metal pipe and tubing. Size range and tolerances, as well as description of mechanical, physical and working properties are presented. 12 pages. Babcock & Wilcox Co.

Circle 542 on page 19

Automatic Packaged Controls

Automatic packaged controls for temperature, torque, viscosity, current, voltage, timing of welding, conveyor overload, speed, plating, battery charging, radiation, moisture content, pressure, deflection, thickness, weight, color and light are described in catalog AC-2. 16 pages. Tipp-Tronic, Inc.

Circle 543 on page 19

Lubrication Fittings

Handy guide to easy selection of Alemite lubrication fittings is provided by catalog 38-23. Special purpose relief, measuring and drive fittings are listed, as well as such accessories as bushings, elbow bodies, extensions, plugs, tools, couplers and nozzles. 32 pages. Stewart-Warner Corp., Alemite Div.

Circle 544 on page 19

Heat Exchangers

Stock sizes, dimensions and weights of Hi-Transfer heat exchangers for use with internal combustion engines, compressors, molding machines, hydraulic equipment, machine tools, torque convertors and turbines are tabulated in bulletin 170. Units have 75 psi working pressure. 4 pages. Whitlock Mfg. Co.

Circle 545 on page 19

Wire Straightener & Cutter

Now available with air clutch and brake is the No. 8-F automatic wire straightening and cutting machine. Construction and operation of this unit are related in detail in folder TC-56. Specifications are given. 6 pages. Lewis Machine Co.

Circle 546 on page 19

Stainless Screw Conveyors

Stainless steel screw conveyors listed in data sheet are kept in stock for immediate delivery. Units are made in industrial and sanitary designs in 4, 6, 9 and 12 in. diameters and 7 ft 10½ in. to 11 ft 10 in. lengths. 2 pages. M-H Standard Corp.

Circle 547 on page 19

Machining Stainless Steel

Pocket-size slide chart offers latest data on turning, drilling, tapping, threading, milling, reaming, welding and lubricating stainless steels. It tabulates speeds and feeds. Relative workability in various operations is given. Carpenter Steel Co.

Circle 548 on page 19

Stainless Brazing Alloys

Characteristics and physical properties of Nicrobraz brazing alloys for stainless and special steels are discussed in terms of shear strength, elongation, oxidation resistance and tensile strength in catalog SD-23. Applications cover many industries. 4 pages. Wall Colmonoy Corp., Stainless Processing Div.

Circle 549 on page 19

Wheels

Types of hubs, bearings, tires and axle bore sizes for wide variety of wheels, including juvenile, light industrial, drive and heavy industrial types are described and illustrated in 1957 wheel reference list and engineering data catalog. Specs of all units are given. 24 pages. Allied Wheel Products, Inc.

Circle 550 on page 19

Stainless Steel Fabrication

Comprehensive coverage is given to fabrication of U.S.S. stainless and heat resisting steels in this manual. Main sections deal with welding, riveting, soldering and joint design; machining, cutting, forming, annealing and pickling; surface finishing and protection; and tabular data. Last section includes tables on properties, weight and gages, and corrosion resistance. 130 pages. United States Steel Corp.

Circle 551 on page 19

Electromagnetic Control

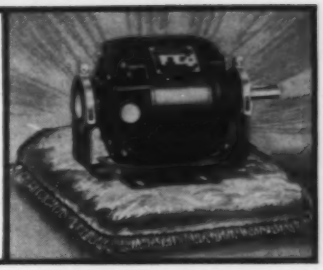
Seven complete catalogs are combined in catalog 57-S on Asco electromagnetic controls. Design and application as well as performance data are given on remote control switches, automatic transfer switches, magnetically held contactors, relays, solenoids and electric plant controls. 170 pages. Available only by writing on letterhead to Automatic Switch Co., Florham Park, N. J.

Gray Iron Foundries

"Buyer's Guide and Directory of Members" is title of latest directory which presents plant location, management personnel, types of castings produced and production facilities of hundreds of gray iron foundries. 78 pages. Available only upon letterhead request to Gray Iron Founders' Society, Inc., National City — E. 6th Bldg., Cleveland 14, O.

tailor-made for You

. . . and every one a perfect fit



No Sir, no ready-made here. Emerson-Electric motors are custom-engineered for your product . . . *designed* for you, *produced* for you and *priced* for you. It is no longer necessary to design your product around a *standard* motor. Emerson-Electric engineers will work with you through every stage of development. You get the product you want with a motor that EXACTLY suits your purposes . . . a custom-engineered motor at *standard motor prices.* Call, wire or write Dept. M-51 today, The Emerson Electric Mfg. Co., St. Louis 21, Mo.

EMERSON-ELECTRIC
of St. Louis

Since 1890

Circle 444 on page 19

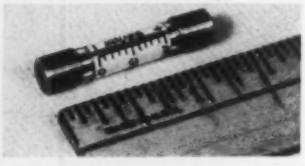
New Parts and Materials

Use Yellow Card, page 19, to obtain more information

Elapsed-Time Indicator

contains anode, cathode and electrolyte

Chronistor is a subminiature elapsed-time indicator which operates on the electroplating principle. It is a miniature electroplating bath, containing an anode, cathode and electrolyte. Unit indicates total number of hours during which any electrical instrument, appliance or component has been in operation. Other applications include determination of periodic overhaul times and component replacement periods, warranty of instruments or equipment, and life-test timing. Current required by the indicator is provided by unit being timed. No auxiliary relays or switches are necessary. **Bergen Laboratories,** 247 Crooks Ave., Clifton, N. J.



Circle 552 on page 19

Miniature Clamp

withstands impact loads of 50 g

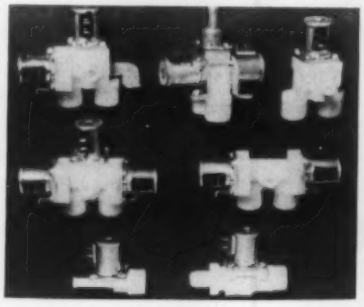
Miniature wire-holding clamp secures wire bundles in aircraft, missiles and limited-space electronic equipment. Made of Nylon/Zytel, unit withstands impact loads better than 50 *g*. When loaded it is highly resistant to fatigue in any position. Wire is placed inside the U-shaped clamp and a keeper is pushed over notched edges, where it locks with high holding power. Several locking positions are available, enabling keeper to adjust itself to size of bundle. Unit is available in sizes from 3/16 to 2½ in., securing from 58,000 to 8,570,000 circular mils of wire. **Dakota Engineering Inc.,** 6641 Crenshaw Blvd., Los Angeles 43, Calif.

Circle 553 on page 19

Water Mixers

have nylon valve bodies

Three lines of water mixers are for use in domestic washing machines, vending machines, dishwashers and drinking fountains. One line consists of seven compact solenoid-operated units ranging from a five-temperature, three-solenoid type to a single-solenoid, one-inlet stop valve. Bodies are nylon, and solenoid coils in all lines are cast in epoxy resins. They are available with 120 and 240-v, continuous-duty, 50/60-cycle ratings. Second line consists of two bimetallic-type thermostatic water control valves. Third line includes four improved controlled solenoid valves which deliver accurate temperature-controlled water despite varying pressures in water-supply system. **Robertshaw-Fulton Controls Co.,** Fulton Sylphon Div., Knoxville 1, Tenn.

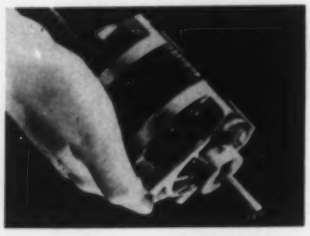


Circle 554 on page 19

Fractional-Hp Motor

for business-machine applications

New 19-frame, two-pole, permanent-split capacitor motor, rated either 1/40 or 1/20-hp, is designed primarily for small business-machine applications such as calculators and adding machines. It operates on 115 or 230 v, single phase, 50 or 60 cycles, and has speed of 3200 rpm. Motor runs either clockwise or counterclockwise and can be made reversible. It has inherent thermal protection. Open, self-ventilated motor is mounted rigidly, or is provided with rubber rings for resilient mounting. **Westinghouse Electric Corp.,** P. O. Box 2099, Pittsburgh 30, Pa.



Circle 555 on page 19

Silicon Transistors

operate at 150-C temperatures

Fifteen silicon transistors in round welded cases are built for use with automatic production techniques, and meet military specifications. They operate stably at tempera-

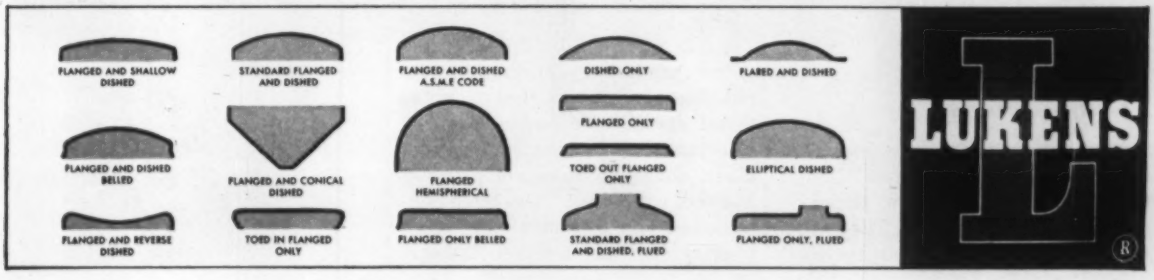
In this Norton Grinder, imaginative designing with Lukens heads simplified construction, saved money.

Improve your product... cut costs... designing with Lukens heads

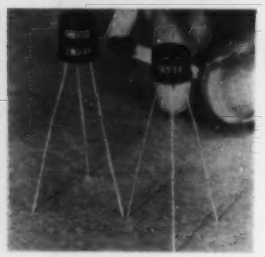
■ Start to think about simplifying *your* designs, even redesigning, with Lukens standard head shapes. For Norton Company, Worcester, Mass., this led to stronger and safer grinding-wheel guards on machines such as this Type U-4 Universal Grinder—plus positive savings in cost and time. Two standard Lukens heads fitted together turned the trick.

Where can preformed Lukens heads reduce design complexity and eliminate fabricating steps in your equipment? Put your imagination to work and see. Others have used them in wheels, valves, chemical equipment, heavy and light machinery. Lukens' fifty-five years as the leading producer of spun and pressed steel heads for many applications are at your service. Write for Catalog 935, *"Pricing and Engineering Data."* Lukens Steel Company, Coatesville, Pennsylvania.

Lukens Offers the World's Broadest Line of Spun and Pressed Heads of Carbon, Alloy and Clad Steels



Circle 445 on page 19



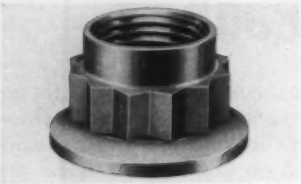
tures to 150 C. Two switching transistors have total switching times down to 100 milli-microseconds. Both are N-P-N grown-diffused types with high alpha cutoff frequencies and low collector capacities. The other thirteen units include three high-frequency tetrodes, five medium-power devices, and five small signal transistors. **Texas Instruments Inc.**, 6000 Lemmon Ave., Dallas 9, Tex.

Circle 556 on page 19

Self-Locking Nut

for 180,000-psi high-tensile bolts

Kaylock H20 self-locking, high-strength 12-point nut is designed to develop the full strength of 180,000-psi high-tensile bolts. It is a one-piece, all-metal unit for use in temperatures to 550 F. Precision wrenching surfaces withstand full wrench-torque requirements of 180,000-psi tension-bolt



applications. Fatigue life exceeds requirements of MIL-B-7838. Nuts are available in sizes ¼-28 through ½-20. **Kaynar Co.**, Box 2001, Terminal Annex, Los Angeles 54, Calif.

Circle 557 on page 19

Silicone O-Rings

for dry-heat service

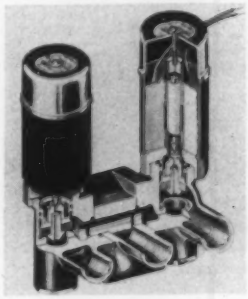
Style 9599 red silicone rubber O-rings are of 70 durometer hardness stock exhibiting low shrinkage and compression set. They are recommended for dry-heat service where synthetic rubber compounds and natural rubber do not maintain their rubber characteristics. Rings resist oxidation, withstand indefinitely continuous exposure to hot air and temperatures to 300 F. In most applications they withstand for long periods of time exposure to dry heat at temperatures from 300 to 500 F. **Garlock Packing Co.**, 406 Main St., Palmyra, N. Y.

Circle 558 on page 19

Solenoid Valve

for three-way flow control use

New three-way duplex solenoid valve is available in three assemblies for mixing, divided flow and



cylinder control operations. Valve is bubbletight and is used at specific pressures from 5 to 1000 psi with both pistons normally closed and at 5 to 500 psi with either or both pistons normally open. It is available in ½ and ¾-in. pipe sizes. Valve is used on air, water, oil or any fluid not harmful to Navy M bronze. It has replaceable, resilient main disks, stainless-steel pilot assemblies and unbreakable piston rings. **Atkomatic Valve Co. Inc.**, 545 W. Abbott St., Indianapolis 25, Ind.

Circle 559 on page 19

Speed Transmitter

is pneumatic and linear

Type 16A pneumatic speed transmitter produces a pneumatic output linearly proportional to rotational speed. It measures speed of rotating machinery, such as turbines, conveyor lines, compressors and mill equipment. Gasketed construction and continuous air bleed prevent dust and weather damage. Bimetallic input shaft automatically varies spacing between magnet and disk with temperature changes. Range is adjustable from 0 to 1600 rpm up to 0 to 2400 rpm by

a fine-range adjustment screw. Optional speed changers extend range to 0 to 320 rpm through 0 to 5300 rpm. Unit measures clockwise or counterclockwise rotation, or 3 to 15-psig output can be split to accommodate both forward and reverse rotation within maximum range limit. **Foxboro Co.**, Foxboro, Mass.

Circle 560 on page 19

Circuit Breaker

for combination lighting and distribution panels

New three-pole, 50-amp, 240-v frame circuit breaker for combination lighting and distribution panels extends the usefulness of QO circuit-breaker panelboards and loadcenters for three-phase, 3 and 4-wire, 240-v ac circuits and single-phase, 2 and 3-wire circuits. Sequence bus connections permit any adjacent single poles to be changed to double poles on any bus, as well as three poles on three-phase bus arrangements. It is available in 15, 20, 30, 40 and 50-amp, 240-v ratings. Operating mechanism is quick-make, quick-break with thermal and independent magnetic trip. Thermal element responds directly

You Can Count On... to Pay Off!

It's the **Original Equipment* idea . . . which simply means that, when you're figuring on electrical or mechanical counters in any new product, it pays to *design them in, when you begin.*

For then Veeder-Root quite likely can save you time and money by adapting or modifying a *standard* counter to your needs, instead of a special which you might specify on your own. This solves the counter problem . . . and saves you time in engineering, purchasing and assembly.

What's more, you give your product new sales-advantages: Direct-reading digits, instead of hard-to-read dials and verniers . . . instant remote indication if needed . . . up-to-the-minute performance records that serve as a basis for production-*Control*, and as proof of your performance guarantee. So don't let counters take a back seat in your new-product plans. *Design them in, when you begin* . . . it pays in many ways. Do you have the newest Veeder-Root Catalog? Write

Series 1205
Reset Magnetic Counter

Everyone Can Count on Veeder-Root

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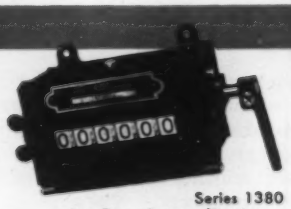
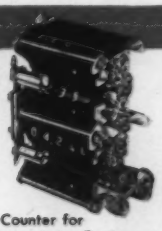
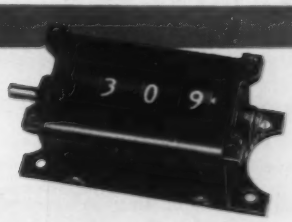


Series 1380
Box-Type Counter (Ratchet, Revolution, or Geared)



4-bank Counter for Radio Transmission Equipment



360-degree Bearing Counter

Circle 446 on page 19

to normal overloads in conductor, while magnetic elements trip breaker, independently, on shorts or dangerous overloads. **Square D Co.**, 4041 N. Richards St., Milwaukee 12, Wis.

Circle 561 on page 19

Springs

for aircraft and missile use

Close-tolerance extension, compression, torsion and flat-steel springs, suitable for aircraft and missile experimental research and development uses and for production work, are available in stock sizes or are made to missile or air-

craft specifications. Materials used include beryllium copper, chrome-silicone, high-nickel alloys, steel music wire and corrosion-resistant wire. Plated or unplated springs are available in many wire sizes, diameters and lengths. **California Spring Co. Inc.**, P. O. Box 22014, Los Angeles 22, Calif.

Circle 562 on page 19

Increment-Start Motors

use two-step, general-purpose starters

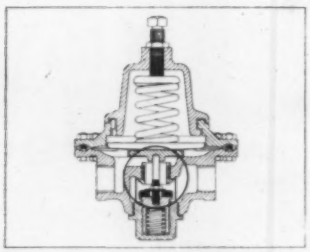
Four-pole, 220-v, 1800-rpm motors of 20 hp and higher utilize two-step, three-pole, general-purpose starters with time delay of 2 to 5 seconds between steps. Wiring diagram is furnished for connecting motor and starter. Need for complex switchgear is eliminated. **Brook Motor Corp.**, 3553 W. Peterson Ave., Chicago 45, Ill.

Circle 563 on page 19

Pressure Regulator

has interchangeable valve disks

Redesigned regulating valve incorporates larger through passage which provides greater capacity



and less turbulent flow pattern. Valve disks are interchangeable to provide quick change from one type of service to another. Reduced pressure range is from 1 to 100 psi, with initial pressures as high as 400 psi. Equipped with built-in strainer, valve is available in bronze, semisteel or steel body. Six sizes from $\frac{3}{8}$ to 2 in. are offered. **Davis Regulator Co.**, 2523 S. Washtenaw, Chicago 8, Ill.

Circle 564 on page 19

Protective Covering

for fine metal finishes

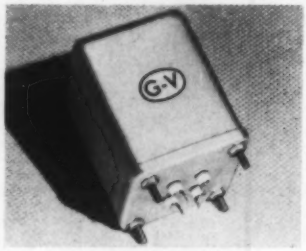
Onco protective covering for fine finished metals withstands sunlight, rain, sleet, smoke, dust and grease. It reflects ultraviolet and infrared rays, is easy to apply and strip, is tenacious and leaves no gummy residue. Material can be stored indefinitely. It has met exacting performance requirements for scribing, shallow drawing, rolling and forming. **Onco Products Inc.**, 201 S. Main St., Middletown, O.

Circle 565 on page 19

Time Delay

is instant-reset type

Type BR thermal time-delay unit resets instantly when its energizing circuit is interrupted, either during timing cycle or after completion. Total delay interval comprises a brief heating period followed by a longer cooling period, and output



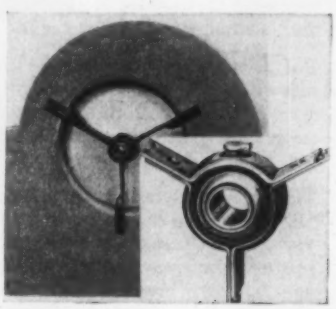
contacts operate when total cycle is completed. Units are available for 9 standard delay intervals from 2 to 300 seconds. Energizing voltage is 28 v dc; time-delay tolerance, $\pm$ 10 per cent. Output contacts are normally open or normally closed, single-pole, single-throw. Ambient temperature range is $-$ 65 to 125 C, and unit withstands shock of 30 g and vibration of 10 g over 5 to 500-cps range. **G-V Controls Inc.**, Hollywood Plaza, East Orange, N. J.

Circle 566 on page 19

Ball Unit Bearing

for heating and air-conditioning use

Pressed steel Hiawatha ball unit bearing has tri-arm mounting with triple cantilever-beam action which unites and pyramids separate strengths of housing and bracket. Multiple pads of 50-durometer Neoprene liner increase resiliency, provide ventilation over bearing, and grip ball surface to prevent rotation. Double-end floating wedge retains ball within formed socket. Ball unit is inserted or removed



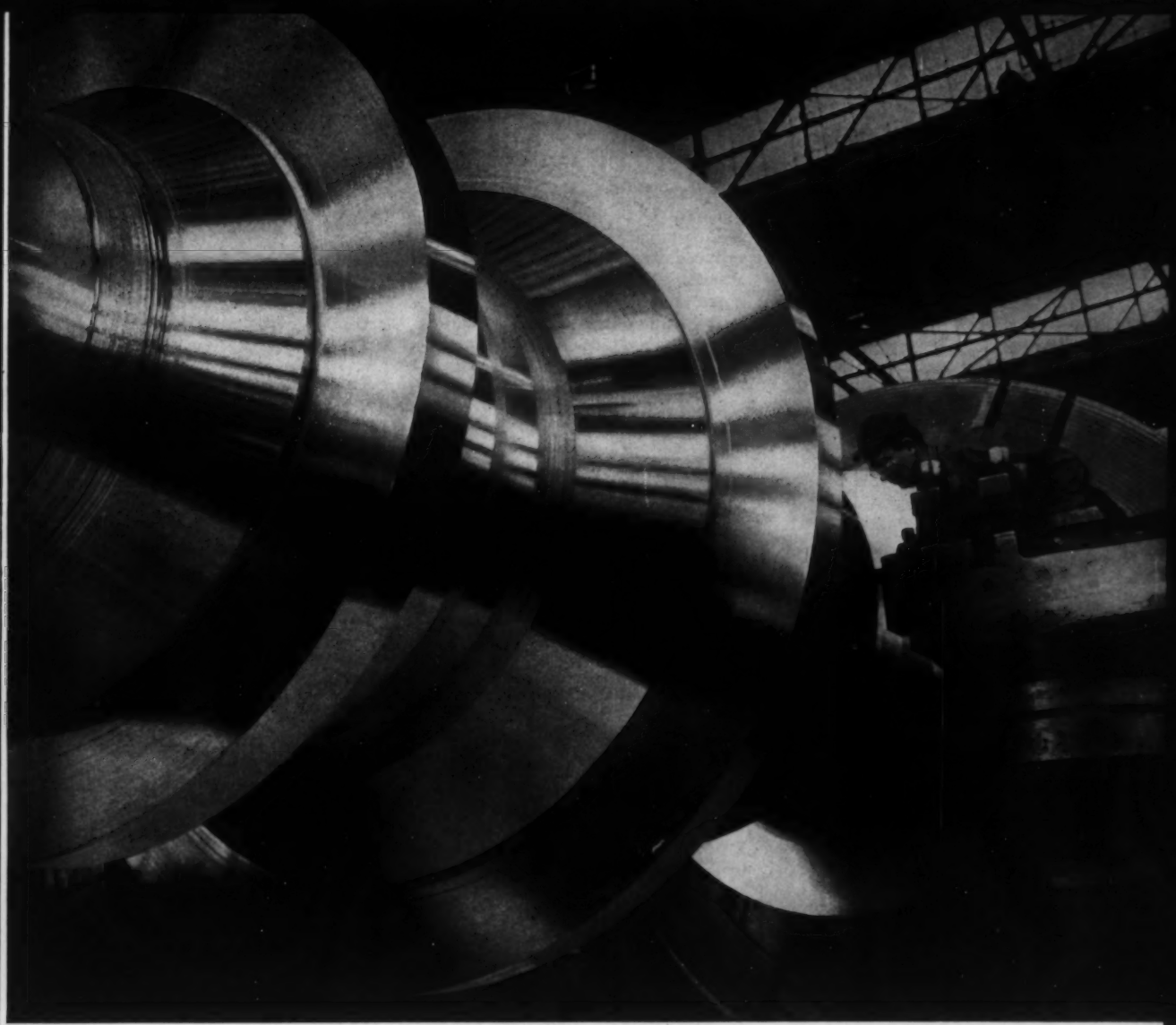
without interfence from assembled oil cup or oil tube of any length. **Triangle Mfg. Co.**, Oshkosh, Wis.

Circle 567 on page 19

Indicator Lamps

are assembled for panel mounting

Indicator lamp assemblies for panel mounting are suited for power switchboards, electronic power supplies and control panels in aircraft, marine, railway and laboratory equipment. They resist severe marine, tropical and atmospheric conditions. Assemblies con-



Will help create new stores of power in Pacific Northwest

This huge forged shaft is one of eight produced by Bethlehem for the generating equipment at The Dalles Dam, on the Columbia River. When finally installed, it will have a part in the vast system of power production now under development in the Pacific Northwest.

Of carbon-vanadium steel, the shaft weighs approximately 190,000 lb; is more than 33 ft long, and has a maximum diameter of 96½ in. Its smallest body diameter is slightly over 38 in. Running the entire length of the shaft is a uniform 15½-in. bore.

Forgings of this size are spectacular, and months of painstaking work go into their planning and manufacture. It's a type of assignment that Bethlehem has been handling for many years. But the big "show pieces" are only a fraction of Bethlehem's output. We are equipped to make and machine any kind of forging ever needed—from giant cylinders, shafts, and columns to midgets weighing a pound or less.

You are invited to check with us when next in the market for press, hammer, drop, or upsetter forgings. Inquiries are welcome, always. Whether your needs are large or small, our engineers will cooperate fully.

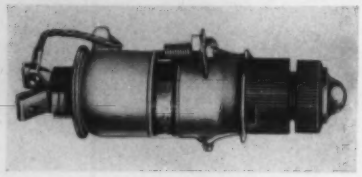
BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Circle 447 on page 19



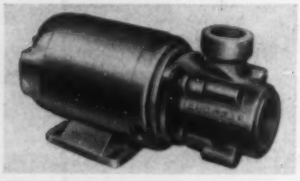
sist of 24-v slide-base telephone-switchboard type lamp, plug-in housing, tubular resistor, bezel and color caps. They can be installed in 21/32-in. holes in panels up to ¼-in. thick. Terminals suitable for No. 12 or smaller wire, located at rear, are screw-type. Long-life lamps have nominal rating of 0.032 to 0.038-amp for use with resistors ranging from 110 to 7100 ohms. **Federal Pacific Electric Co.**, Eastern Switchgear Div., 888 N. Keyser Ave., Scranton, Pa.

Circle 568 on page 19

End Suction Pumps

operate at 3500 rpm
single and three-phase

Centri-Pac close-coupled end suction pumps are available in 21 sizes with horsepowers from 1/6 to 5, capacities to 150 gpm and heads to 140 ft. They are suited for use in air-conditioning units, cooling towers, hot-water circulators, and for general service. Units operate at 3500 rpm, single and three-phase. Impellers are balanced for



smooth, quiet operation. Mechanical seals have stainless-steel parts with carbon stationary seal ring. **New York Air Brake Co.**, Aurora Pump Div., 31 Dearborn St., Aurora, Ill.

Circle 569 on page 19

Rigidized Teflon

provides improved
mechanical characteristics

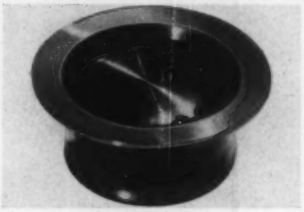
Enflon rigidized Teflon (filled) surpasses normal Teflon in characteristics such as load and temperature resistance, coefficient of friction and wear resistance. It is reasonably stable at 575 F and permits higher unit loading and closer tolerances at higher temperatures. Available in tape, rod, tubing and slugs, the material machines well and does not cause undue wear on carbide tools. It is suited for bearings, valve guides, pressed washers, sleeve caps and bearings, bushings, inserts, rotating mechanical seals and gaskets. **Enflo Corp.**, Route 38 at Airport Circle, Pennsauken, N.J.

Circle 570 on page 19

Diaphragm Seals

have low-temperature
flexibility

LPF diaphragm seals have maximum flexibility characteristics over temperature range of −150 to 400 F. They have exhibited only 1 per



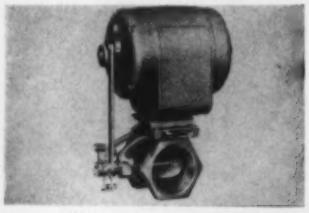
cent compression set after months of actual usage. Seals are available in a variety of designs and sizes for use through a full range of applications. **Bellofram Corp.**, Blanchard Rd., Burlington, Mass.

Circle 571 on page 19

Control Motor

operates final elements in
automatic control systems

Actionator reversing, capacitor-type electric motor operates rotary, slip-stem and butterfly valves, dampers and other final elements in automatic control systems. It is available in two basic models: one for two-position and floating control, and the other for proportioning control. Motor incorporates a gear train that permits selection of timings from 7.5 to 120 seconds, depending on model. Built-in internal brake holds a dead-weight load to 200 lb. Limit switches vary travel from 10 to 350 deg for one model and from 10 to 160 deg for the other. Unit operates under



temperatures from 25 to 150 F. Electrical ratings are 115 or 208 v at 60 cycles and 230 v at either 50 or 60 cycles. **Minneapolis-Honeywell Regulator Co.**, Industrial Div., Wayne & Windrim Aves., Philadelphia, Pa.

Circle 572 on page 19

Pintle-Type Chain

for woven-wire belts

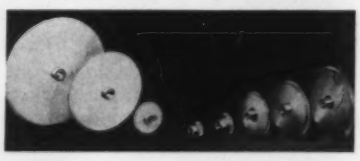
Pintle-type chain developed for use on woven-wire belts incorporates a heavy shoulder that provides equal bearing surfaces at both open and closed ends of the link. It has a free-floating connecting pin to provide wear around full 360-deg circumference of pin. Pin diameter has been increased to permit carrying heavier loads. Chain operates on standard sprockets. **Cambridge Wire Cloth Co.**, Cambridge, Md.

Circle 573 on page 19

Precision Gears

for servo breadboarding

Spur, spring and clutch gears, and bevel and miter gears are suitable for servomechanism use. Spur gears in tooth multiples of 8 and 10, with 14½-deg pressure angle, are 48 and 64 pitch and have minimum and maximum pitch diam of 9/16 and 4 in. respectively. Gears with pitch diam of 1 in. or less are stainless steel and have 3/16-in. face width. Gears with pitch diam



over 1 in. are aluminum with stainless-steel insert hubs, and have ⅛-in. face width. All gears are made to AGMA Precision Class 2

5 YEAR WARRANTEE
Your Scotts Electric Mower is unconditionally guaranteed for 5 years. This guarantee is possible because of exceptional materials, engineering and workmanship.
O. M. SCOTT & SONS
Scotts
SCOTTS

O.M. Scott & Sons selects Monarch Permanent Mold Castings for more casting value per dollar

In the words of O. M. Scott & Sons, famous for lawns, "We have been dreaming for 20 years of producing the perfect lawn mower. We have spent the last five years designing the Silent Scott®." The result is a new concept in lawn mowers, underwritten by their five year unconditional warrantee. Look for it at your neighborhood garden or hardware store.

Monarch Aluminum Velvaglaze® permanent mold castings are used for the 6 major parts of the assembly. The main reasons are strength, durability, performance and appearance. Monarch's ability to provide a "one-source", non-competitive analysis of all practical production casting methods contributed to the effectiveness of Scott's design. This same practical approach in your next development program can help you to obtain better end-products at lower factual end-costs.

The 6 major castings are Velvaglazed®—a natural lustrous aluminum, mar-resisting finish.

SINCE 1913
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ALUMINUM
PIONEERS IN CASTING PROGRESS

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MONARCH ALUMINUM MFG. COMPANY—9205 DETROIT AVENUE—CLEVELAND 2, OHIO—OLympic 1-1700
MANUFACTURERS OF: *Aluminum Permanent Mold Castings • Zinc Die Castings • Aluminum Die Castings • Exclusive Velvaglaze Finishing • and Spectraglaze, colorful Porcelain Enamel on Aluminum Permanent Mold Castings.*

standards. Spring and clutch gears are available in the same range of sizes and variations as spur gears, except that spring gears have minimum pitch diam of 1¼-in. and clutch gears of 1⅜ in. Bevel and miter gears are available in 3/16 and ¼-in. bore sizes, pin hub only. **Beckman/Helipot Corp.**, Newport Beach, Calif.

Circle 574 on page 19

Miniature Relay

has built-in full-wave rectification

Class 11 6PDT hermetically sealed miniature relay has built-in full wave rectification which provides operation that closely approaches direct current from all frequencies

to and including 400 cps. Other advantages include increased operating sensitivity, high contact pressures, greater resistance to vibration, wide variation in voltage or current, and operation free of ac hum. Unit has 20-pin miniature plug-in header. **Magnecraft Electric Co.**, 3350T W. Grand Ave., Chicago 51, Ill.

Circle 575 on page 19

Solenoid Valve

for operating pressures up to 130 psi

Miniature solenoid valve, designated K-27H, is 3⅛ in. high and 1⅞ in. in diameter. It is for use on all common industrial fluids, including water, oil, gas and air, at operating pressures to 130 psi. Applications include gas or liquid flow control in vending machines, automatic production machinery, process controllers, test benches, spraying and lubricating equipment. Unit is normally closed and has spring-loaded plunger with soft seat for bubble-tight shutoff, brass bar-stock body and two-wire, continuous-duty solenoid. Design pro-

vides positive operation in any position, including side and inverted mounting. **General Controls Co.**, 801 Allen Ave., Glendale 1, Calif.

Circle 576 on page 19

Footswitches

for heavy-duty industrial use

Hercules line of heavy-duty industrial footswitches includes 40 models. Primarily designed for use as pilot devices in connection with control circuits of contactors or starters, the switches are also suitable for direct control of small motors and other electrical devices. They have cast-iron enclosures, safety guard, and pedal position trip point. Two basic types are available—momentary contact and maintained contact — with four classes in each type. These are: general-purpose heavy-duty; watertight enclosure, NEMA Type 4;

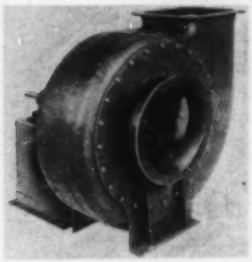
explosionproof for hazardous locations, Class 1, Group D, NEMA Type 7; and high dc rated switches. **Linemaster Switch Corp.**, Woodstock, Conn.

Circle 577 on page 19

Corrosion-Resistant Fans

of resin-bonded glass fiber

Designed for corrosive air-handling jobs, Type FG corrosion-resistant, impact - resistant, resin - bonded glass fiber fume fans do not support combustion. Fans afford excellent chemical resistance to a variety of acids, salts, gases, organic materials and other corrosives in temperatures to 225 F. Fan housing has integral stainless-steel studs molded in for attachment to bearing stand. All exposed rotor parts are encased in thick glass fiber. Fans are available in stand-



ard capacities to 34,000 cfm. **Buffalo Forge Co.**, 490 Broadway, Buffalo, N.Y.

Circle 578 on page 19

Brazing Material

for high-temperature applications

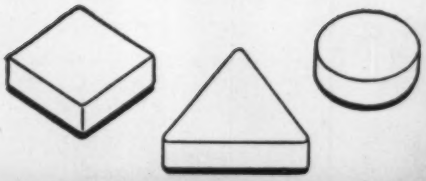
Braze-Clad N is supplied as a predetermined thickness of silver brazing alloy on one or both sides of pure nickel base. It is useful for high-temperature applications, such as stainless-steel honeycombs, electronic tubes, jet aircraft and nuclear structures. Material is used as a brazing shim where close control of flow of brazing alloy is necessary and where joints must be free of voids. Material can be blanked, stamped, rolled, bent and shaped. Alloy, metallurgically bonded to the base, cannot crack or peel off. **American Silver Co. Inc.**, 36-07 Prince St., Flushing 54, N. Y.

Circle 579 on page 19

Drive Unit

in 1½ through 15 hp

Motor-clutch-brake drive with controls provides fast or slow starts with acceleration, deceleration and/or stops in automatic cycles up to 30 per minute. It is available in 1½ through 15-hp sizes, all with constant torque, and at standard motor speeds between 600 and 1800



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CA-610 THROW-AWAY TOOL BLANKS

improved this cutting operation

150%

A leading West Coast manufacturer now uses Carmet CA-610 tool blanks for machining components of jet engines and gas turbines. Since switching to this special steel-cutting carbide grade, production has sharply increased from 28 parts per blank *to more than 80.*

Carmet throw-away blanks are designed for any type of tool holder. This same manufacturer reports that the ease and speed with which used blanks may be exchanged for new ones has reduced downtime for tool change-over by 7%.

Advantages such as these are important in *your* industry, too. Call your Carmet dealer TODAY for his advice on any production problems you may have . . . or write *Allegheny Ludlum Steel Corporation, Carmet Division, Detroit 20, Mich.*

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. . . Completely revised, the 16th Edition of the Carmet Catalog contains the latest information on all Carmet grades, and on Carmet blanks, tools, die sections, etc.; also gives details on special pre-forming and how to order special parts.

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Circle 449 on page 19

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and Only CUNO offers you

5 DISTINCT TYPES OF FILTER MEDIA

♦ EDGE-TYPE ♦ WIRE-WOUND ♦ SCREEN
♦ FIBER CARTRIDGE
♦ POROUS METAL

THE New WHITE CELLULOSE MICRO-KLEAN® FILTER CARTRIDGE

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5-MICRON FILTRATION . . . removes *all* particles down to this size *and* a large percentage of particles down to 1 micron or smaller.

COMPLETE SANITATION . . . for water, liquid food processing and other applications where *clarity, purity* and complete absence of any filter-imparted *taste* are essential.

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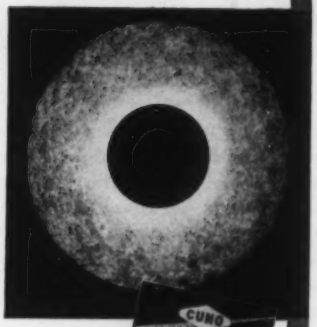

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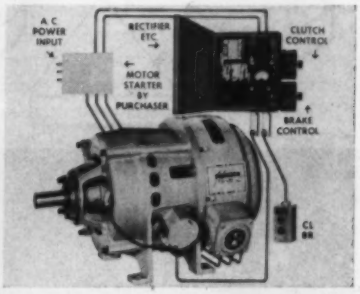


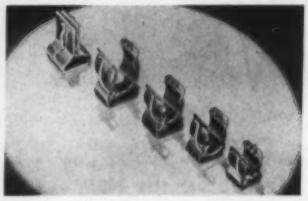
rpm. Applications include operation of veneer clippers, shearing and punching machines, conveyors, indexing tables and other machinery under continuous or intermittent service, with almost any combination of automatic stop-start or speed-up, slow-down regulation. Clutch magnets produce maximum torque on low dc voltage and current. **Ericsson Merritt Inc.,** 504 Pine St., Lockport, N.Y.

Circle 580 on page 19

Fuse Clips

withstand vibration and shock

Wire-reinforced fuse clips and jaws of electrolytic copper provide good conductivity with low heat rise. Steel wire reinforcing produces necessary grip on fuses to with-



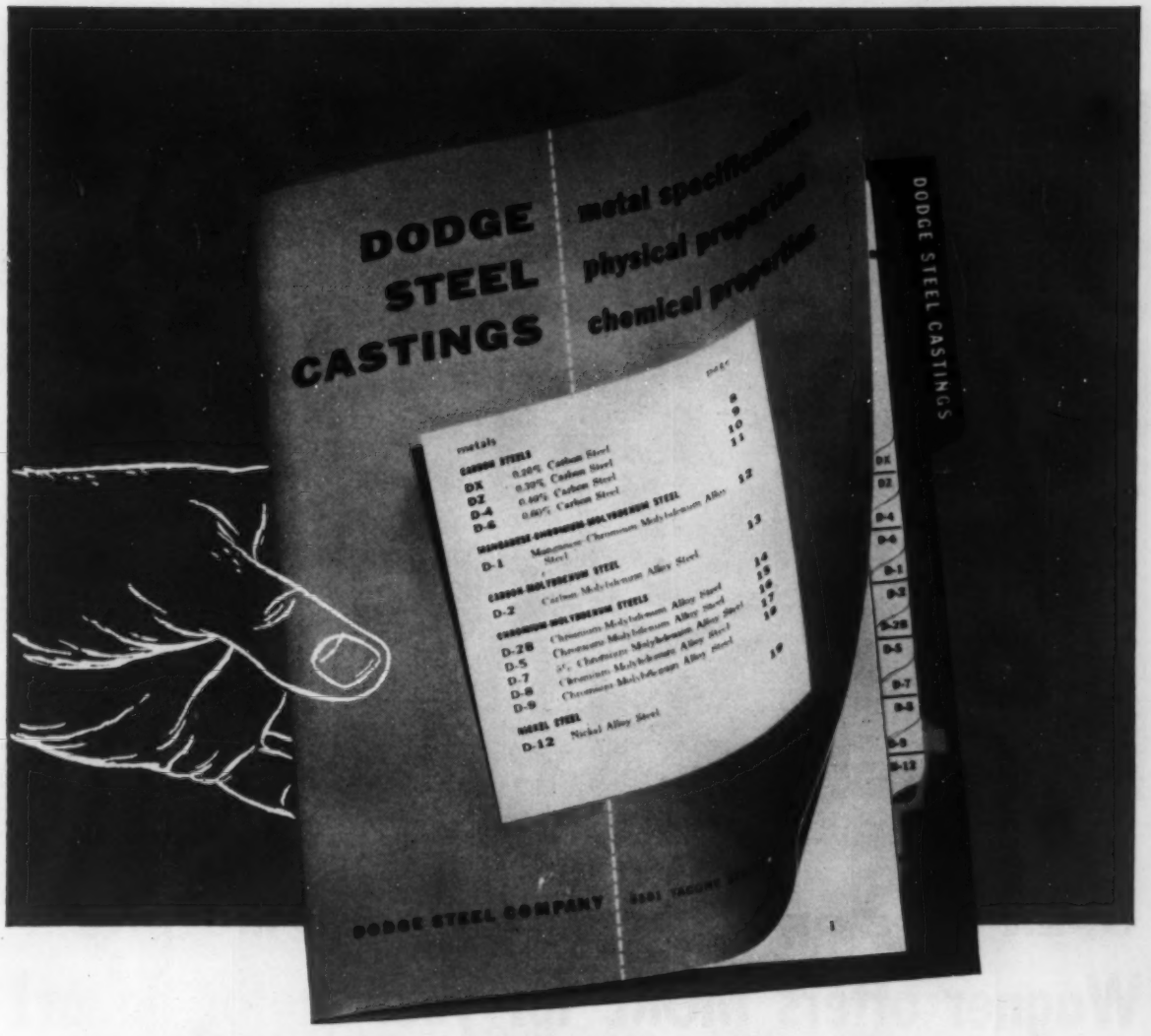
stand excessive vibration and shock. Clips are available in 30, 60 and 100-amp, 250-v, and 30 and 60-amp, 600-v sizes. **Ilsco Corp.,** Dept. L., 5741 Mariemont Ave., Cincinnati 27, O.

Circle 581 on page 19

Accelerometer

for jet aircraft and missile use

Model GAL ac accelerometer provides good sensitivity, relatively high, very linear ac output, low sensitivity to perpendicularly applied accelerations, good resistance to vibration



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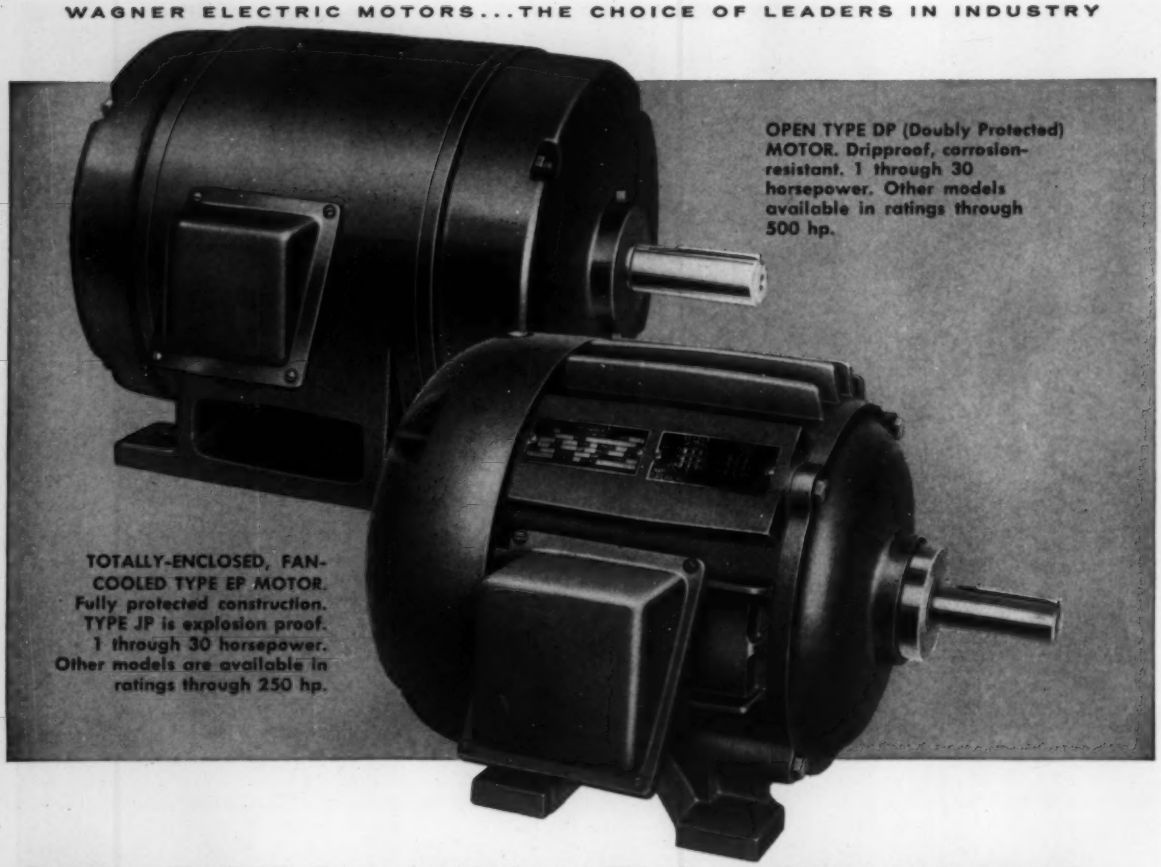
WAGNER ELECTRIC MOTORS...THE CHOICE OF LEADERS IN INDUSTRY


OPEN TYPE DP (Doubly Protected) MOTOR. Dripproof, corrosion-resistant. 1 through 30 horsepower. Other models available in ratings through 500 hp.
TOTALLY-ENCLOSED, FAN-COOLED TYPE EP MOTOR. Fully protected construction. TYPE JP is explosion proof. 1 through 30 horsepower. Other models are available in ratings through 250 hp.

OPEN TYPE OR TOTALLY ENCLOSED MOTORS...

Wagner offers MORE for your motor dollar!

- **MORE POWER IN LESS SPACE**... These motors are built in NEMA frame sizes 182 through 326 U. They pack more power into less space for easier handling and stocking—require less space for installations.
- **CORROSION-RESISTANT FRAMES** ... Both types are built with rugged, corrosion-resistant cast iron frames. Motor feet are cast as an integral part of the frame for maximum strength and rigidity.
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- **COOLER OPERATION**... Special baffles direct a cooling flow of air through the DP motor. Types EP and JP are fan-cooled and have ribbed frames to increase the surface area for more efficient cooling.
- **LONGER BEARING LIFE**... These motors can be re-greased when desired to prolong bearing life. Fresh grease can be added—old grease removed through openings provided in the bearing housing.
- **WAGNER DEPENDABILITY**... These two motors have the same high Wagner quality, will give the same long life performance, that have made Wagner Motors a *known* value for sixty-five years.
- Let a Wagner field engineer, expert on motor applications, show you how these motors can be applied to your needs. Call the nearest of our 32 branch offices, or write us. Bulletins MU-202 and MU-203 give complete information on these Wagner Motors. Write for your file copies today.

M57-4

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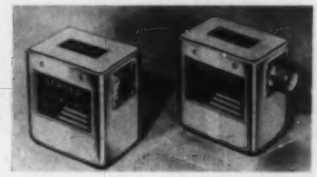
and shock, and high linear and stable damping over ambient temperature range of −65 to 275 F without use of a heater. Standard instrument range is from ±0.1 to



±10 *g*. Operational life is 1000 hr minimum. Unit meets acceleration and shock requirements of MIL-E-5272A, Procedure 1. It is for use in jet aircraft and missiles. **Genisco Inc.**, 2233 Federal Ave., Los Angeles 64, Calif.

Circle 582 on page 19

Pressure Snubbers

of brass, aluminum or stainless steel

New pressure snubbers have ⅛-in. NPT male and female pipe connections. They are brass, aluminum or stainless steel, available in three porosities for oil, water and gases,

including steam. Snubbers have applications in the aircraft, automotive and refrigeration industries. **Chemquip Co.**, 460 W. Broadway, New York 12, N. Y.

Circle 583 on page 19

Drum Switches

for small ac or dc motors

Three drum-switch models are for reversing, across-the-line starting of small conveyors, shop tools, door operators, oil burners, and other applications for small ac or dc motors. Type IR permits instant reversing of standard single-phase ac motors. Type PR models are for conventional reversing duty. Switches have butt-wipe, self-cleaning contact action, and silver-alloy contacts. Other fea-

Large NBD cast and machined gear blank

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This is a heavy, 34-inch, machined gear blank. But you name your weight! NBD can handle it in gear blanks, bearings and bushings up to 20,000 lbs. Machined to precise tolerances . . . sizes up to 72-inch diameters. Any size, large or small, guaranteed sound!

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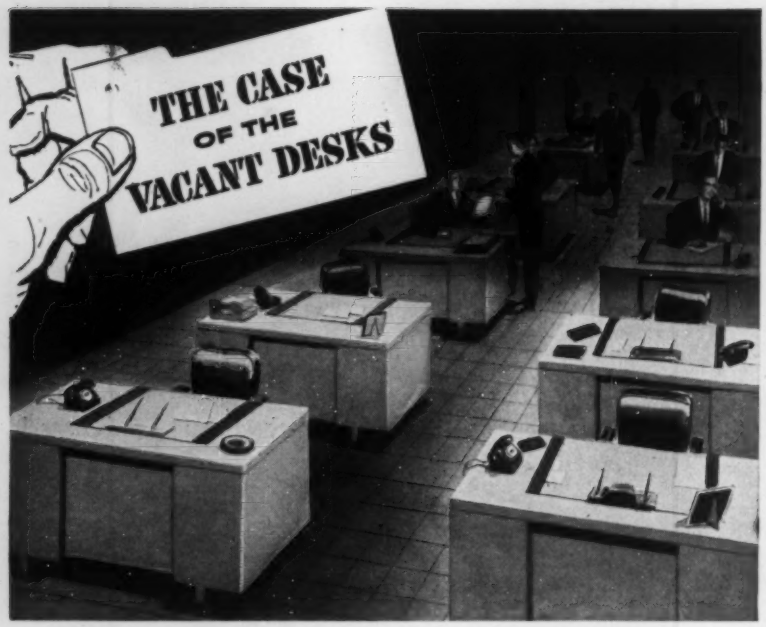
Circle 453 on page 19



WHENEVER we see the desk of one of our Field Engineers vacant, it's a good sign. Chances are, he's on a trip, making calls with Foote Bros. Distributor personnel—helping solve a power transmission problem *in the field*. That's why we call them Field Engineers.

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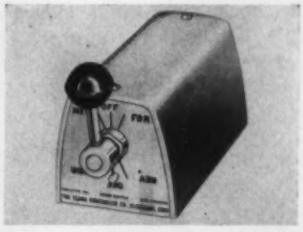
New Parts



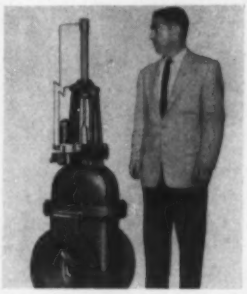
tures include ample wiring space, insulated barriers between phases, and readily-accessible contacts. Switches are furnished in NEMA 1 enclosures for surface or flush mounting. Ratings are ¼-hp for dc motors, 1 hp for 115-v, single-phase ac motors, 1½ hp for 230-v, single-phase ac motors, and 2 hp for 220/550-v, two or three-phase ac motors. **Clark Controller Co.**, 1146 E. 152nd St., Cleveland, O.

Circle 584 on page 19

Hydraulic Actuator

operates gate valves

This unit, consisting of pump, pressure switch, cylinder, reservoir and motor, provides two separate and distinct pressures for closing and opening gate valves and similar applications. Closing pressure range of 2000 psi is provided on



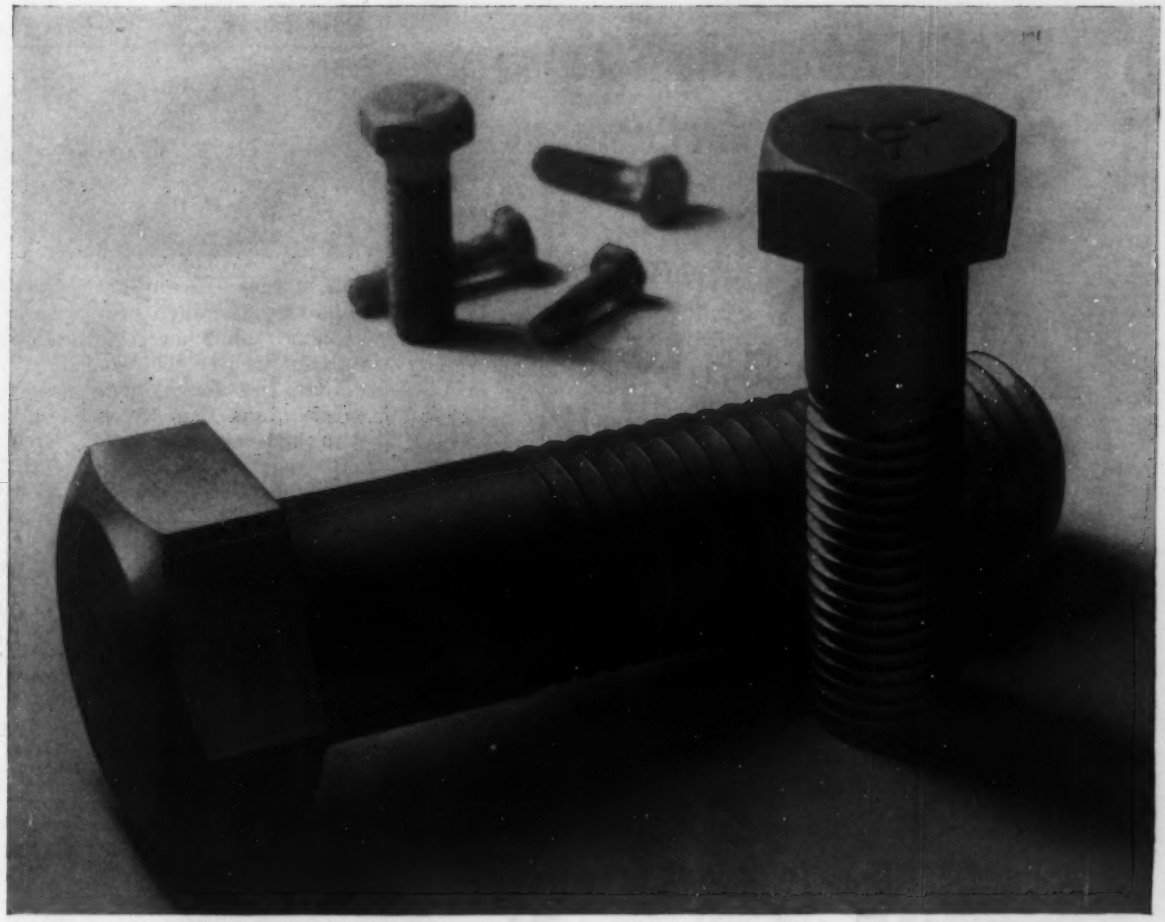
one side of the cylinder, and an opening pressure range of 3000 psi is provided on the other. Unit is offered in a full range of types and motor sizes, with explosion-proof housings available for standard units. **Oil-Dyne Inc.**, 2115P W. Marquette Rd., Chicago 36, Ill.

Circle 585 on page 19

Circuit Breakers

for aircraft applications

Two miniaturized Klixon aircraft circuit breakers have three moving parts: actuator, slide and thermal



Cleveland upset forged hexagon head cap screws make your assemblies stronger and safer

Cleveland's upset forging process puts an extra measure of fastener muscle into your assemblies. The flow lines in every hexagon head cap screw follow the contour of the head, eliminating the planes of weakness along which shear might occur under the dynamic stress of heavy impact and vibration.

Cleveland hexagon head cap screws are manufactured from a wide variety of steels and in many different tensile strengths. In most cases, a Cleveland standard will serve as well as a special and will be much less expensive. Check the chart at the right for the one best suited to your needs. Then see your local Cleveland distributor. He stocks Cleveland hexagon head cap screws in sizes and physical properties to meet the most exacting demands of modern machinery design. All standard size cap screws in bright and quenched and tempered steels are available without delay—alloy steels on short notice. And remember, your distributor is backed by the most up-to-date production facilities and the largest factory stock of hexagon head cap screws in the world.

TENSILE STRENGTHS OF CLEVELAND HEXAGON HEAD CAP SCREWS

Product	Size, in.	Tensile Strength, psi
Bright	Up to 7/8 incl. 1/2 to 1 1/8 incl. Over 1 1/8 to 1 1/2 incl.	85,000—105,000 75,000—100,000 65,000 min.
Quenched & Tempered (SAE Grade 5)	Up to 3/4 incl. Over 3/4 to 1 incl. Over 1 to 1 1/2 incl.	120,000 min. 115,000 min. 105,000 min.
Quenched & Tempered (SAE Grade 6)	Up to 5/8 incl. Over 5/8 to 3/4 incl.	140,000 min. 133,000 min.
Alloy (SAE Grade 7)	Up to 1 1/2 incl.	130,000 min.
Alloy (SAE Grade 8)	Up to 1 1/2 incl.	150,000 min.
Bright	Over 1 1/2 to 2 1/2 incl.	55,000 min.
Quenched & Tempered	Over 1 1/2 to 2 1/2 incl.	90,000 min.
Alloy	Over 1 1/2 to 2 1/2 incl.	125,000 min.

Note: Higher physicals, through use of selected alloys, can be supplied on special order.

GET YOUR COPY NOW — Pocket-size card giving you physical properties of Cleveland hexagon and socket head cap screws and Cleveland Place bolts.

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4444-6 Lee Road, Cleveland 28, Ohio
WAREHOUSES: Chicago • Philadelphia • New York • Los Angeles

Circle 455 on page 19

MESSAGE from the "NO" men of Laminated Shim Company

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...and **NO** dirt between layers—ever!

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STAINLESS STEEL with laminations of .002" or .003"	ALUMINUM with laminations of .003" only
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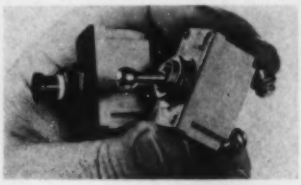


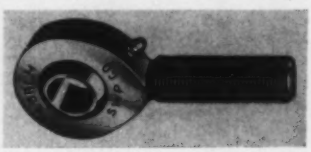
disk. They are available with either toggle switch or push-pull actuator. Units have high rupture capacity to over 4000 amp, 120 v ac, trip-free design, high current capacity, and glass Melamine case with high arc resistance. Each unit weighs less than 1½ oz. **Metals & Controls Corp.**, Spencer Thermostat Div., Attleboro, Mass.

Circle 586 on page 19

Rod-End Bearings

for aircraft and missiles

Two-piece, self-aligning, plain, spherical rod-end bearings reduce lost motion in linkages and withstand excessive vibration. They carry heavier loads than antifriction types and take greater

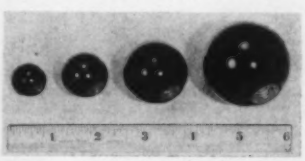


radial and axial thrust loads. Bearings are available in male and female types in sizes for ¼ to ¾-in. bore. Capacities of radial ultimate loads are from 7000 to 33,000 lb. **Southwest Products Co.**, 1705 S. Mountain Ave., Monrovia, Calif.

Circle 587 on page 19

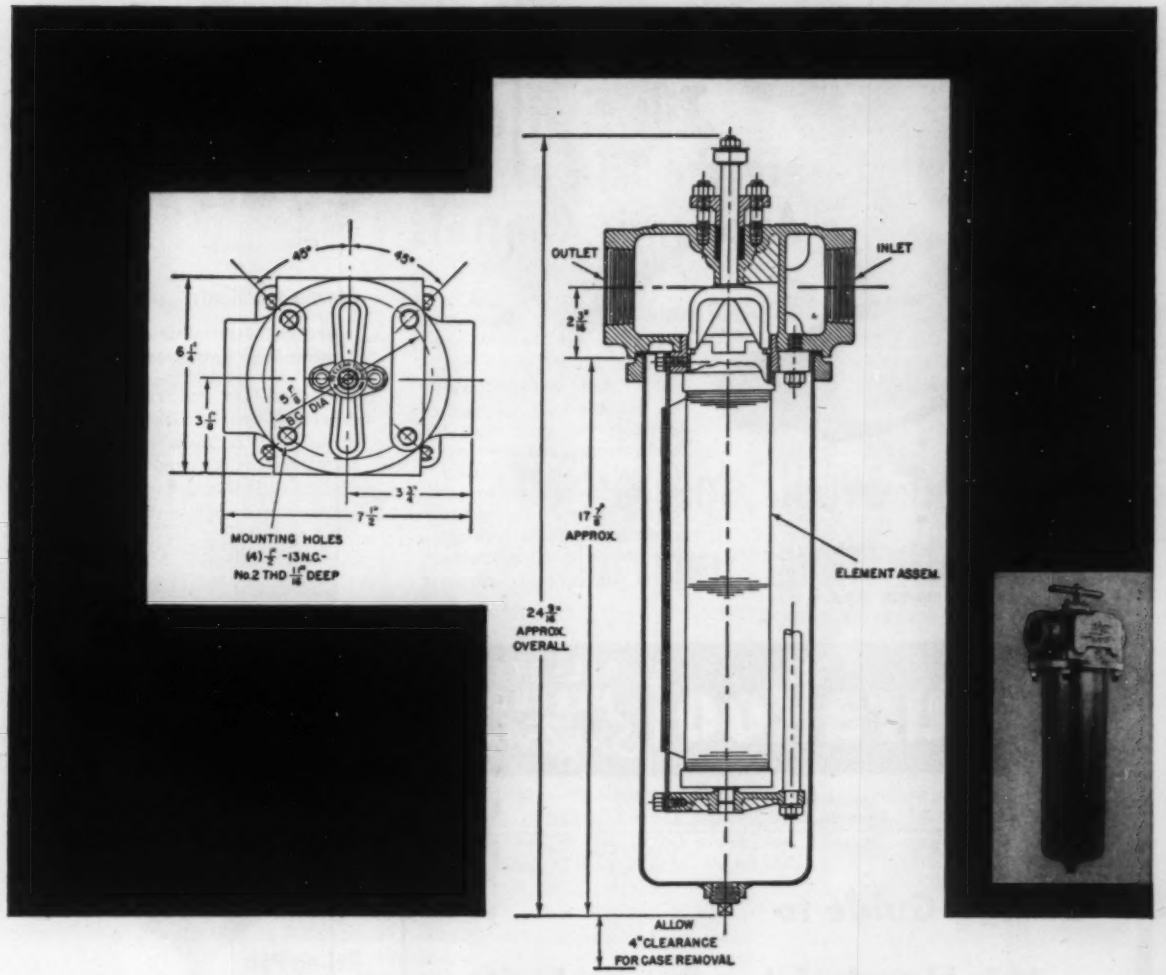
Plastic Knob

for control levers



This ¾-in. diameter ball plastic knob is designed primarily for use on control levers. It is available with 10/32, ¼-20 brass inserts and can be obtained in a variety of special threads. **Dimco-Gray Co.**, 207 E. Sixth St., Dayton, O.

Circle 588 on page 19



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FOR EXAMPLE... This one standard Purolator filter is exactly right for all these "special" filtration problems:

inks, paints,
varnishes, machine tool coolants,
greases, vitamin solutions,
as well as fuel and lube oils.

This filter's specifications may recommend it for a problem of yours. If not, you're almost certain to find a standard Purolator filter that does meet your needs—exactly.

SPECIFICATIONS... This is Purolator filter model G-141J with simplex full flow metal element oil strainers. It is designed for primary or first stage filtration and can be installed on pressure or suction side of pump. Recommended for maximum capacities of 40 to 80 GPM, dependent on spacing which varies from .003 to .010. Relief valves set from 10-12 to 50 PSI are incorporated in several models. Motor driven knife blade to clean element can be furnished whenever conditions make manual rotation impractical. Head is made of high tensile cast iron, body of drawn steel. Inlet and outlet connections are 2", drain plugs are provided. Maximum pressure: 125 PSI; weight: 37 lbs.

Remember, if these specifications don't match your needs, there's probably a filter that does at Purolator. Find out. Send in your problem.

Filtration For Every Known Fluid

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Rahway, New Jersey and Toronto, Ontario, Canada

Circle 457 on page 19

DURAKOOL Tilt Switches are the Life of your Automatic Controls

MILLIONS OF CYCLES WITHOUT FALTERING

This steel-clad Durakool mercury tilt switch has unique construction features that deliver years of trouble-free performance on the most difficult assignments you can find. Operating under sealed-in, pressurized hydrogen gas, it takes 24 hours, fast cycling schedules in stride. 7 sizes, 1 to 65 amperes. Send for Bulletin 525.

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Durakool ALL-STEEL MERCURY *Switches*

Circle 458 on page 19

Design Guide to

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Here, in one book—148 pages, with 24 tables, 119 charts and 171 illustrations—is what the designer should know about adjustable speed.

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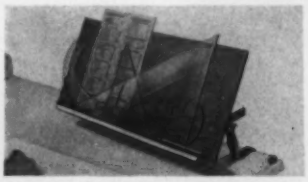
ENGINEERING DEPARTMENT

EQUIPMENT

Clamp-On Shelf

has eight possible mounting positions

Keep-Shelf is quickly clamped on drawing board, desk, work table or bench. It locks level or can be tilted to any desired angle. Eight possible mounting positions provide a variety of uses in drafting rooms,



engineering departments, shops, offices, shipping rooms, schools, home hobby and work shops. Unit measures 8 x 19 in. and is attractively finished. **Downs Industrial Illustrators,** 15906 James Couzens Highway, Detroit 38, Mich.

Circle 589 on page 19

Ruling Pen

push button refills nibs from cartridge

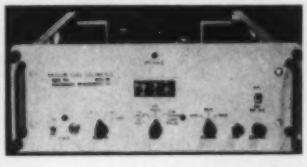
Rule-O-Matic pen is filled in less than 2 seconds by a cartridge. Each cartridge contains 55,000 in. of ruled lines of quick-drying India ink. Pen has rustproof, stainless-steel nibs. **Clover House,** Dept. 116, Box 1107, Santa Monica, Calif.

Circle 590 on page 19

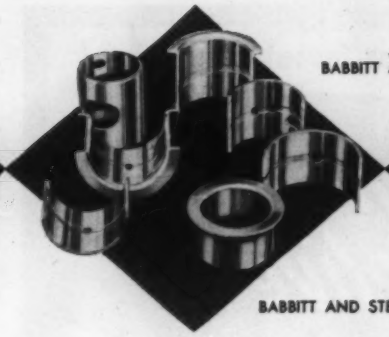
Vacuum-Tube Voltmeter

has lighted digital dial

Three-wheel register of digital voltmeter reads to 999. Indicator lights point off decimal point and indicate plus or minus. "Off-scale"

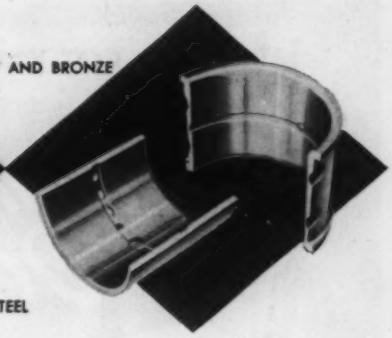


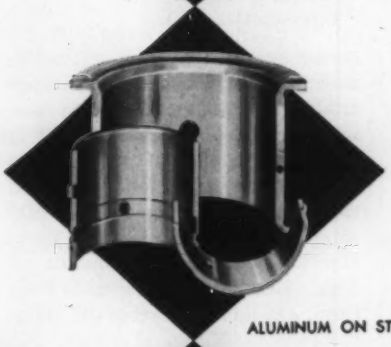
CAST BRONZE



BABBITT AND BRONZE

BABBITT AND STEEL





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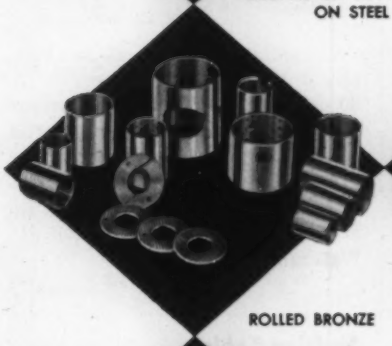
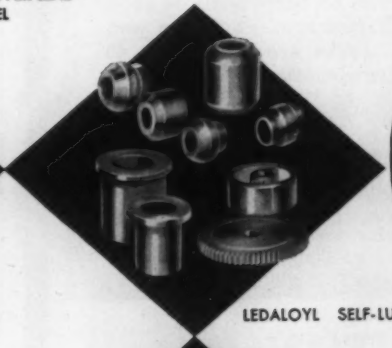
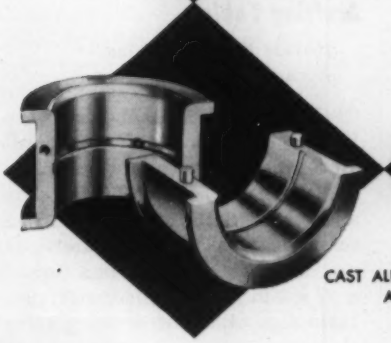


ROLLED BRONZE

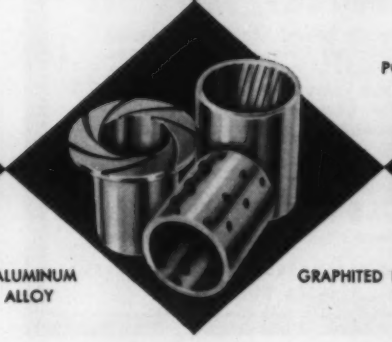


LEDALOYL SELF-LUBRICATING

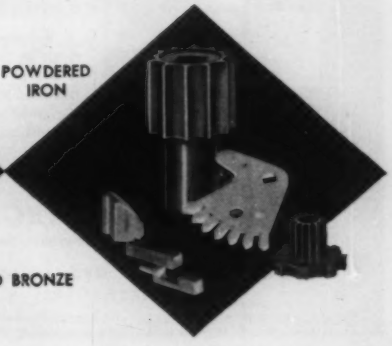
JOHNSON Bearings



CAST ALUMINUM ALLOY



GRAPHITED BRONZE



POWDERED IRON

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light indicates quantity over register capacity. Voltmeter circuitry provides ±0.1 per cent accuracy. **Performance Measurements Co.,** 15301 W. McNichols Rd., Detroit 35, Mich.

Circle 591 on page 19

Ozalid Machine

compact table-top reproduction unit

Streamliner 200 is a compact table-model printer which will reproduce drawings, tracings and other material up to 42 in. wide. Unit is modestly priced, but incorporates features normally found only in more expensive floor models. Machine is 22 in. high and 27 in. deep, allowing placement in smaller offices. **General Aniline and Film Corp.,** Ozalid Div., Emma St., Binghampton, N. Y.

Circle 592 on page 19

Fluid Pressure Cell

measures differential pressures to 60 psi

Differential pressure cell is available in three pressure ranges: ±15, 30 and 60 psi. Output is 3 mv per v; linearity is up to 0.1 per cent full scale. Units may be used with line pressures to 90 psi. **Baldwin-Lima-Hamilton Corp.,** Electronics & Instrumentation Div., 42 Fourth St., Waltham, Mass.

Circle 593 on page 19

Drafting Tables

provide ample working, storage and filing space

Overall size of these tables is 106 in. long and 36 in. deep. Desk provides working space on adjustable-angle drawing board, 60 in. wide and 36 in. deep, and on attached reference table. Full-size drawings are stored conveniently in a flat 37 x 27 x 2-in. drawer under reference table top. Base of drawing table

Circle 460 on page 19

provides filing space in a box drawer and two standard-size filing cabinet drawers. Drawing board is natural finish, dressed white pine. All other parts of the unit are gray-enameled steel. **Republic Steel Corp.**, Berger Div., Canton 5, O.

Circle 594 on page 19

Panel Instruments

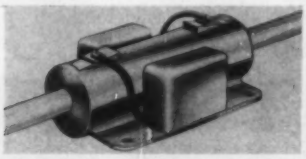
ac and dc units have open-face design

Wide-Vue rectangular panel instruments have open-face design and longer scale lengths. Open-face cover permits wide-angle readability of instrument scales. Instruments are custom-built in 2½, 3½ and 4½-in. models with any practical range, ac and dc. Two movements are available: a standard magnet type, or self-shielded core-magnet meter movement. **Simpson Electric Co.**, 5200 W. Kinzie St., Chicago 44, Ill.

Circle 595 on page 19

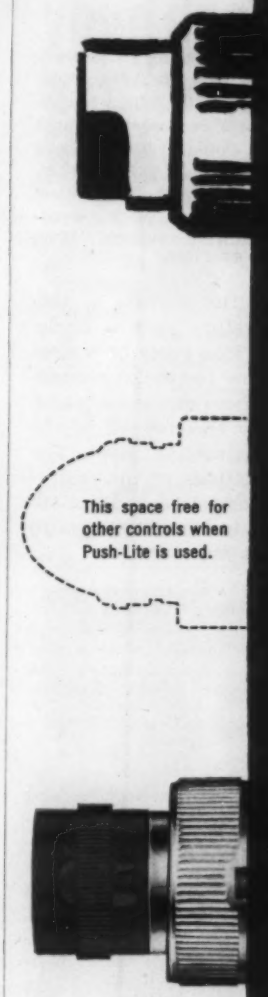
Ultrasonic Flowmeter

measures mass flow with 1 per cent accuracy



Utilizing modification of an ultrasonic beam by liquid flow, instrument measures flow rates under wide environmental conditions without obstructing fluid path. Unit provides 5-v full-scale output for feeding to telemetering or recording system. Special instruments measure volumetric flow as well as mass flow. **Gulton Industries Inc.**, Vibro-Ceramics Div., 212 Durham Ave., Metuchen, N. J.

Circle 596 on page 19



NEW PUSH-LITE* SAVES HALF THE SPACE AND REDUCES COST

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The new unique Push-Lite with its button-shaped plastic lens combines the functions of both a pushbutton and indicating light. One push transmits the appropriate signal and, at the same time, energizes the indicating lamp.

Push-Lites are liquid-tight as are other operators and lights in the Westinghouse Oil-Tite* pushbutton line. Precision-machined fits and neoprene seals will not allow liquids to reach electrical parts.

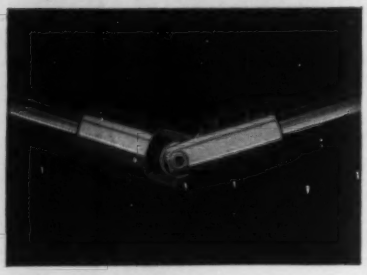
For more information about Oil-Tite pushbuttons ask for the new booklet (B-7022) or the 72-page Pushbutton Guide (B-6749), a catalog of all Westinghouse pushbuttons. Write to Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Penna. or call your local Westinghouse distributor.

*Trademark J-30253

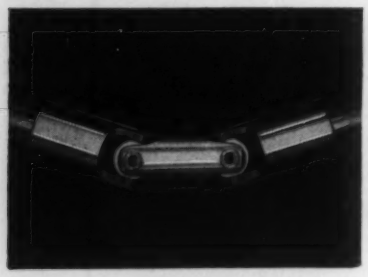
YOU CAN BE SURE... IF IT'S Westinghouse

Circle 461 on page 19

How Curtis helped a design engineer "BEAT THE HEAT"



This single universal joint in a ribbon-stripping machine was operated at a 34° angle. The joint heated up, wear was excessive. (Curtis Joints have been tested at angles up to 37°, but we do not ordinarily recommend angles greater than 30°.)



Curtis engineers recommended a *double* Curtis joint, which reduced the angle to 17° per joint. Result: no overheating, improved efficiency, longer life.

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Circle 462 on page 19

THE ENGINEER'S Library

Recent Books

Mechanical Engineering Laboratory Instrumentation and its Application. *By Jesse Seymour Doolittle, professor of mechanical engineering, North Carolina State College; 396 pages, 6 by 9 in., clothbound; published by McGraw Hill Book Co. Inc., 330 West 42nd St., New York 36, N. Y.; available from* MACHINE DESIGN, *$6.50 postpaid.*

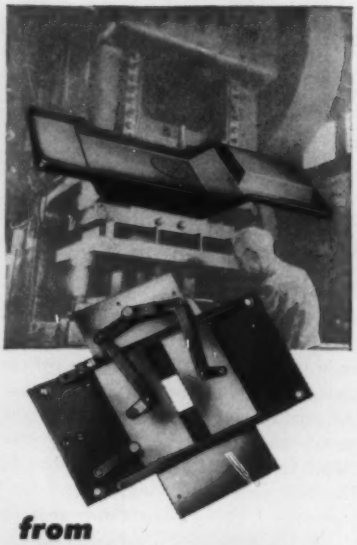
In general, the purpose of this text for laboratory work is to describe the various types of instruments available for making measurements of those quantities which are frequently encountered in the mechanical-engineering field. The use and limitations of the instruments are stressed, as well as the care required in installing them to obtain correct measurements.

Induction Heating Practice. *By D. Warburton-Brown; 192 pages, 6 by 9 in., clothbound; published by Philosophical Library Inc., 15 East 40th St., New York 16, N. Y.; available from* MACHINE DESIGN, *$10.00 postpaid.*

This book is a detailed and up-to-date study of the process and deals particularly with its practical application to industrial problems. It is intended for the production-design engineer interested in the possibilities of the process. The author gives invaluable information on the design of components or assemblies to facilitate use of the process. The book deals with various applications, first giving general notes on each and then going on to specific examples, with full production data.

Metal Castings. *By Joe Lawrence Morris, Los Alamos Scientific Laboratory, University of California; 296 pages, 6 by 9 in., clothbound; published by Prentice-Hall Inc., 70 Fifth Ave., New York 11, N. Y.; available from* MACHINE DESIGN, *$7.35 postpaid.*

This book presents current infor-



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Circle 463 on page 19

mation on the subject, emphasizing the principles of casting rather than procedural detail. Of special interest to the designer are the sections on metallurgy of castings, a section on casting design considerations, and one on welding and forging of cast products.

Government Publications

A Design Manual for Regenerative Heat Exchangers of the Rotary Type, PB 121469. *By Harold Sogin and Kamal-Eldin Hassan, Illinois Institute of Technology; 122 pages, 8 by 10½ in., paperbound; available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.; $3.25 per copy.*

Results of investigations into thermal design of rotating generative heat exchangers for aircraft gas-turbine power plants are assembled in this manual for the designer. Hausen's regenerator theory is developed in a form directly applicable to the rotary machine. A numerical method to calculate the performance of unbalanced regenerators is included. Pressure-drop and heat-transfer data are assembled for flame-trap and wire-screen matrices. Effect of the regenerator performance on the thermodynamic cycle is discussed.

Analog Computer Techniques. *By Clarence L. Johnson, U.S. Air Force Institute of Technology; 264 pages, 6 by 9 in., clothbound; published by McGraw Hill Book Co. Inc., 330 West 42nd St., New York 36, N. Y.; available from* MACHINE DESIGN, *$6.00 postpaid.*

Designed as an aid to those learning to use electronic analog computers (or electronic differential analyzers), this book makes becoming an experienced computer operator easier for the engineer. Following the introductory and general material on electronic analog computation, the volume gives specific techniques for the solution of difficult or unusual problems. The book treats in detail the use of diodes and differential relays in analog computation. Emphasis is given to function generating techniques, including methods of representing functions of more than one variable.

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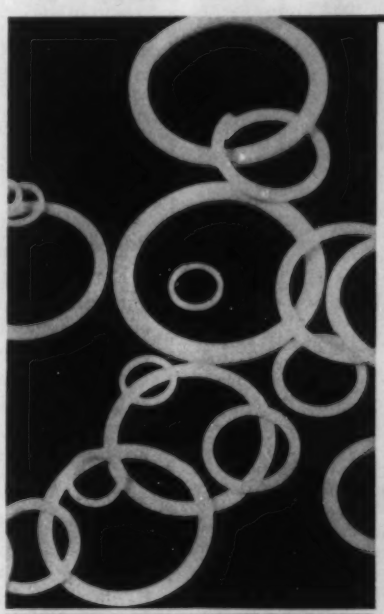

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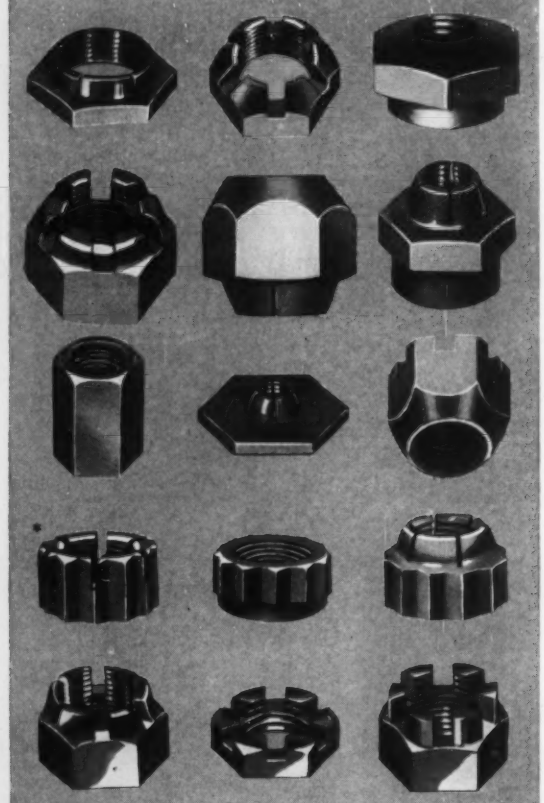

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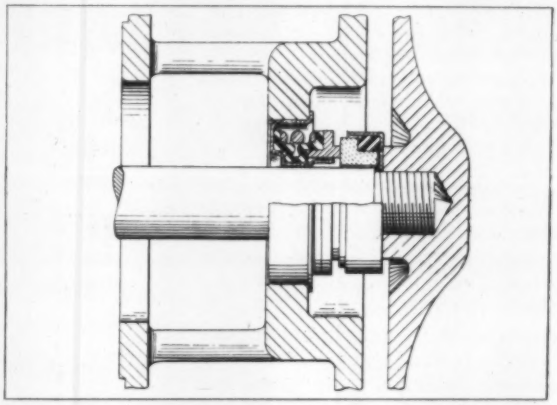
NOTEWORTHY

Patents

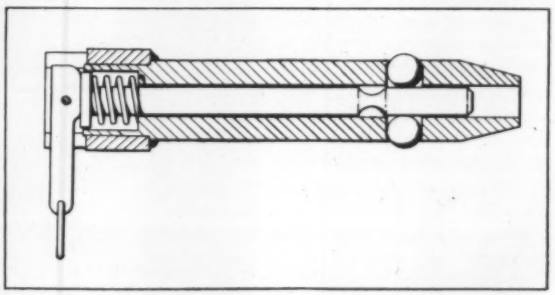
Shaft Seal

Service life of a fluid seal for rotating shafts, employing a rotating ceramic seat member, is extended by the method of mounting the ceramic seat. Shown here in a typical centrifugal-pump installation (impeller at extreme right), the seal employs a metallic shell with a resilient liner to hold the ceramic element under constant radial compression. Effect is to stop possible shattering of ceramic material when it is subjected to either mechanical or thermal shock. Seal is particularly adapted for use where fluids contain abrasives such as fine silts. *Patent* 2,785,913 *assigned to Crane Packing Co. by Archie J. Solari.*



Ball-Detent Clevis Pin

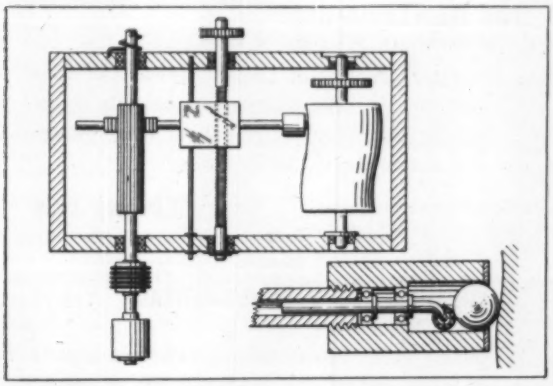
Design of an "automatic" clevis pin, incorporating cam-actuated locking balls, provides protection of the pin and its operating mechanism when forcefully driven into a tight clevis hole. Before initial insertion of the pin, the operating lever is axially aligned with the pin axis, a position which compresses the spring and aligns the locking balls with the necked-down cam annulus. Pressing the pin part way into the hole forces the balls into the annulus and



Circle 466 on page 19

holds the spring in the compressed state. The lever is then moved to the protected right-angle position, allowing the pin to be hammered home without damage to the lever mechanism. When the balls clear the clevis hole, action of the spring returns the mechanism to the locked position. *Patent* 2,786,383 *assigned to D. W. Price Corp. by Eugene Bachman.*

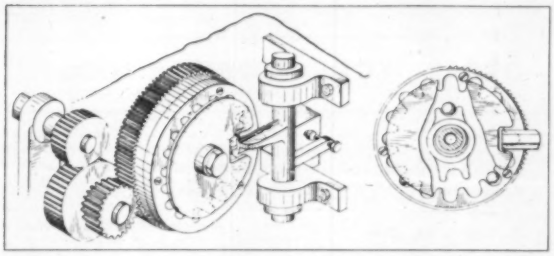
Rolling-Ball Cam Follower



Sliding friction between follower and cam is entirely eliminated in a three-dimensional cam follower that utilizes a rolling-bearing contact. Regardless of the direction of relative cam-follower movement, direct thrust on the ball is supported by a pivoting caster. Caster mount enables it to automatically orient its axis parallel to the axis of ball rotation. Accuracy and sensitivity of the assembly is high, since only the extremely small lateral guiding forces on the ball are applied through sliding friction surfaces. *Patent* 2,788,677 *assigned to General Precision Laboratory Inc. by Arthur F. Hayek.*

Irregularly Operating Control Mechanism

Haphazard or irregular control motions are produced by a mechanism that finds typical use in yarn-spinning frames where irregularly spaced enlarged



threads (so-called slubs) are desired. Action is based on the haphazard falling of one or more tumblers from one to another circumferentially spaced pockets inside a hollow rotating member. Tumblers protrude axially and engage or trip an externally mounted trip lever, producing desired random mechanical signal. *Patent* 2,788,666 *assigned to Hayeshaw Ltd. by Samuel Roscoe.*

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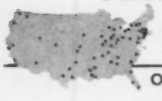

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BPA NBP

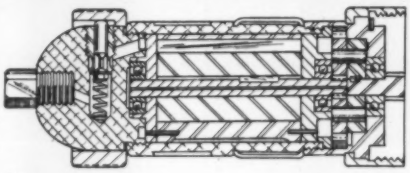
Photo courtesy Signode Steel Strapping Co.

His new speed depends on air power that stalls consistently!

Tensioning steel strapping on big compressible bundles can be hard work. But this man is using a new model air-powered strapping tool, and air power does the hard work—fast. He pre-sets any tension up to 1600 pounds, and gets it every time.

The power comes from a Keller Tool rotary vane air motor. Its lightness and compact design give the tool real mobility. It can take the rough handling, dust, and temperature changes encountered in shipping rooms and on loading docks. Most important of all, it delivers a pre-set tension by running until it stalls. Far from burning out when stalled, the air motor's consistent stall torque, variable through air pressure regulation, is the basis of the tool's key ability to deliver "right tension every time"!

If you can use power like this in small space, investigate Keller Tool rotary vane and axial piston air motors. Send for Bulletins 70 and 71.



Keller Tool OORM-12-L rotary vane air motor used by Signode delivers ⅓ h.p., yet weighs only 2¼ lb. Non-sparking. Free speed is 1200 r.p.m. Other Keller Tool air motors have free speeds of from 300 to 10,000 r.p.m.

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IN GENERAL INDUSTRY, CONSTRUCTION, PETROLEUM AND MINING

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Here's how centralized lubrication savings soon pay for a Farval system

FARVAL—
Studies in Centralized Lubrication
No. 200

● Interested in a system that produces savings to pay for itself in a few months? And protects your investment in expensive equipment for ten, twenty, or even thirty years or more?

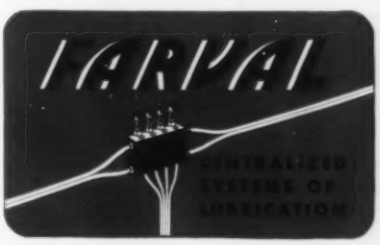
If so, you'll want this new Farval Bulletin 101. It illustrates and describes the application of Farval Centralized Lubrication Systems to a dozen types of equipment—draglines, shovels, crushers, mills, cranes, conveyors and other machinery used in the non-metallic producing and processing industries.

Millions of industrial bearings are protected by Farval. Thousands of new systems go in each year—on equipment both new and old. Farval always pays its way. You'll want the whole story. Why not investigate? Then invest!

Write for Bulletin 101 today. The Farval Corporation, 3287 East 80th Street, Cleveland 4, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.

Proved in 30 years of service, Farval manual and automatic centralized lubrication systems protect bearings of thousands of machines in industry. Wherever you see the familiar Dualine valve manifolds, dual lubricant lines and central pumping station, you know a machine is being properly lubricated.



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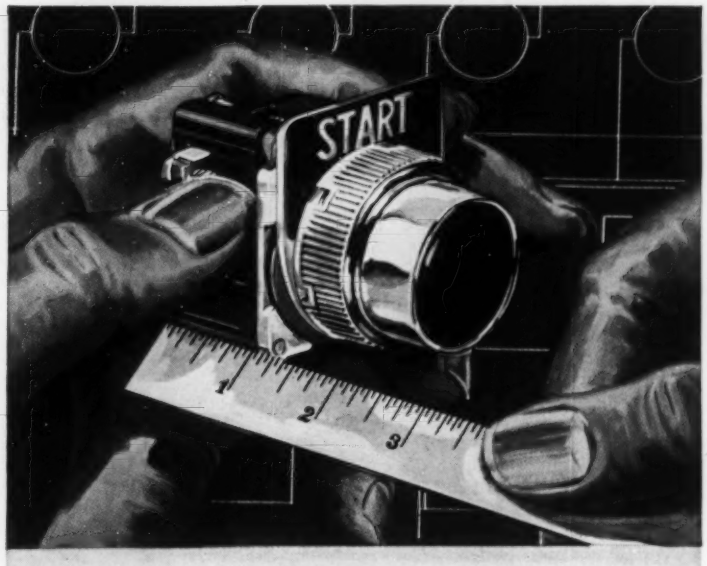
☆ ☆ ☆

Machine designers say these new heavy duty pushbutton units have no equal and prove it by adopting them as standard equipment



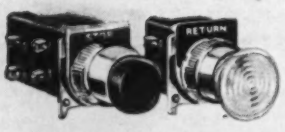
These are the world's smallest heavy duty pushbuttons. They require a behind-the-panel depth of only 1 3/32". This is 40% less space than needed by the next smallest units on the market. Double-pole contact blocks are available in all combinations of normally open and normally closed contacts. Each control circuit is electrically and mechanically isolated from the other. Each circuit is clearly identified and all terminals are color coded. Rapid on-the-job circuit additions are obtained by stacking contact block on contact block.

☆ *they install easier*

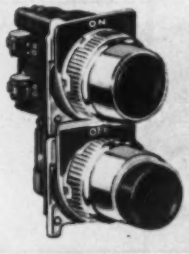
☆ *they work better*

☆ *they last longer*

Design engineers are quick to recognize that these new heavy duty pushbuttons have *everything*. There is nothing on the market like them. They are amazingly compact to require the least back-of-panel depth. They are one-hole mounting and they are oil tight. They easily provide for as many as eight separate control circuits per pushbutton, eight completely isolated heavy duty contacts either normally open or normally closed. The buttons may be flush type, the extended type or with mushroom heads. They can be black, red, yellow, green or gray. See the new one-button control station, C-H Roto-Push. See the easiest-to-install maintained-contact pushbutton attachment and the means for padlocking any of the standard pushbuttons. There are both knob and key operated selector switches in this complete line. Also matching indicating lights and the new automation safety light, PresTest. Be sure you have complete information *now*. Write today on your company letterhead for a copy of the new Cutler-Hammer Pushbutton Handbook Pub. EL-178. CUTLER-HAMMER, Inc., 1310 St. Paul Ave., Milwaukee 1, Wisconsin.

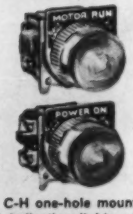


These pushbuttons may be flush type, extended type or with mushroom heads . . . in a wide range of colors for quick control identification. Standard, large, and jumbo size legend plates fit every type of operator and indicating light in the entire line.



A maintained-contact pushbutton assembly that saves more than its entire cost by installation savings. New attachment with its pushbuttons mount in minutes; no fussy adjustments. Neither alignment nor spacing of units is critical. Pushbuttons will not bind or stick; always operate perfectly.

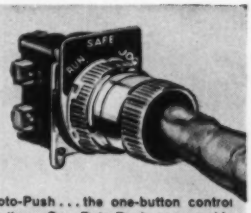
CUTLER-HAMMER
MOTOR CONTROL
C-H



The C-H one-hole mounting oil-tight indicating lights with new wide-visibility lenses are the most visible from all angles by actual light meter tests. Available in either transformer or resistor types. Lenses offered in six different colors.

PresTest . . . the self-testing indicating light. Vital to safety and proper use of machines, particularly in automation. PresTest now permits instant proof light is NOT off because of burned-out bulb. Merely pressing on the light lens disconnects bulb from its normal circuit and checks it on a test power supply. Resistor and transformer types available.

The most complete line of oil-tight selector switches on the market. Key or knob operated; two or three position. Positions may maintain contact or have spring return. Three standard contact blocks provide a wide range of circuit combinations with the use of just a single block. Unlimited circuitry by adding blocks.



Roto-Push . . . the one-button control station. One Roto-Push can provide all the control functions for which two or three separate pushbuttons would be used normally. Available in a wide range of selector and button operators. Roto-Push simplifies panel design and saves installation time to cut costs. Improves machine-operator efficiency.

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